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of the

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C/O THE DIRECTORATE OF SUGAR & VANASPATI
MINISTRY OF FOOD & AGRICULTURE
(DEPARTMENT OF FOOD)
NEW DELHI
INDIA

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Murari Lal Agarwala, S.K.G. Sugar Ltd., P.O. Lauriya, Dist. Champaran, Bihar
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R. N. Agarwal, Ratna Sugar Mills Co. Ltd., Shahganj, Dist. Jaunpur
S. B. D. Agarwala, c/o Burmah-Shell Oil Storage & Distributing Co. of India Ltd., Calcutta

THE CUBAN DELEGATION
(From left) : Roberto Barreto-Dominguez, W.E. Dickinson, R. Gonzalez Rivera, W.A. Powe.

Indonesia—G.A.W. Wagenaar.

Nicaragua—M.C. Alcantara.

THE PHILIPPINES DELEGATION

Front Row (from left) : J.J. Mirasol, E.T. Infante, A.S. Hizon, M.B. Villano.
Back Row (from left) : J.T. Tapay, J.O. Sason.

THE MEXICAN DELEGATION

A. G. Gallardo, P.S. Khankhoje.

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*Anand Prakash Agarwala, c/o Shri Shambhoo Nath Agarwala, R.B. Lachmandas Sugar & General Mills Ltd., P.O. Jarwal Road, Dist. Bahraich, U.P.

*C. N. Agarwal, Hanuman Sugar Mills Ltd., P.O. Motihari, Dist. Champaran, Bihar

*M. S. Agarwal, Rajasthan Government Sugar Factory, Sri Ganganagar, Rajasthan

G. C. Aich, Rohtas Industries Ltd., Dehri-on-Sone, Dist. Shahabad, Bihar

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Amritsar Sugar Mills Co. Ltd., Rohana Kalan, P.O. Rohana Mills, Dist. Muzaffarnagar, U. P.

K. G. Apte, Phalton Sugar Works Ltd., Sakharwadi, Dist. Satara North

L. V. Apte, Phalton Sugar Works Ltd., Sakharwadi, Dist. Satara North

M. L. Apte, Phalton Sugar Works Ltd., Sakharwadi, Dist. Satara North

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Shatrughan Autar, H.R. Sugar Factory Ltd., Bareilly, U.P.

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*A. L. Bhatia, Lakshmi Sugar & Oil Mills Ltd., Hardoi, U.P.

*Sitaram Bhawasinghka, Shree Anand Sugar Mills Ltd., Khalilabad, Dist. Basti, U.P.

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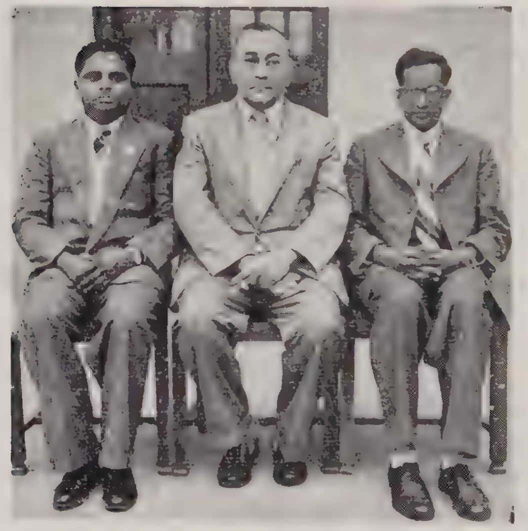

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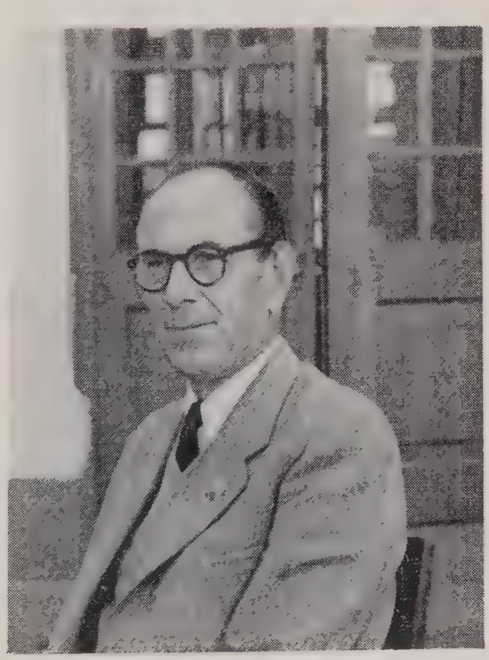

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J. C. Carter, Kaumakani, Kauai
Douglas Ednie, Pepeekeo
L. A. Faye, Kekaha, Kauai
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J. Sandison, Eleele, Kauai
H. K. Stender, C. Brewer & Co., Hilo
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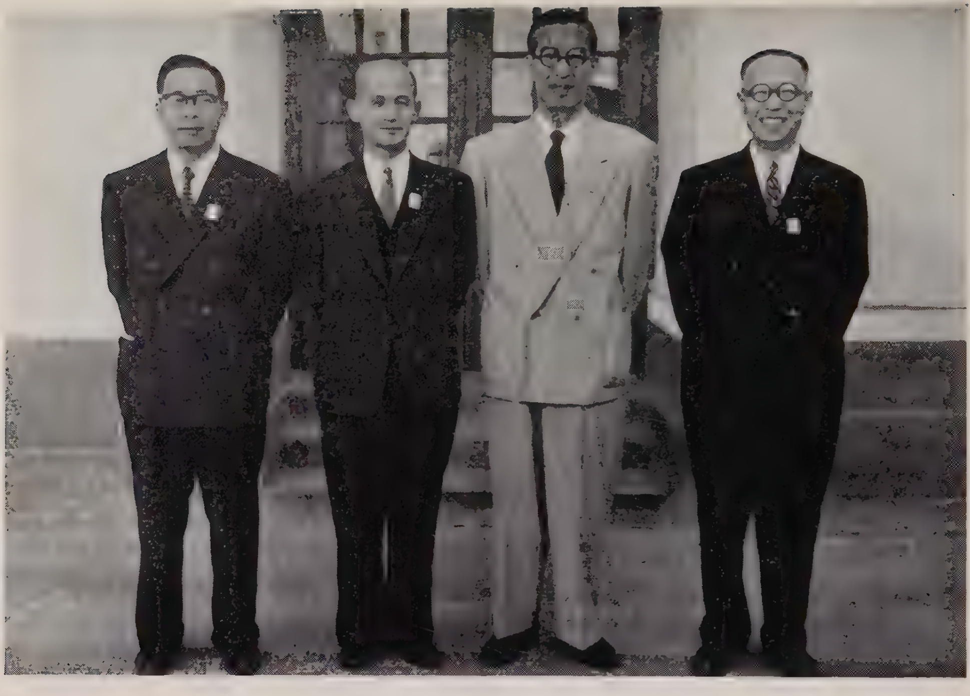
THE EGYPTIAN DELEGATION
(From left) M.H. Amin, Y. El-Alaily, M.M. el-Syed

Czechoslovakia—J. Bartosek.

France —R.Francois.



THE JAPANESE DELEGATION
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Iran—S. Samimy.

Reunion—E. Hugot.

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SUMMARY OF MEMBERSHIP

REGIONAL SECTIONS

		Attendance 9th Congress		Total Membership
Australia, New South Wales and Fiji		5		21
Queensland		17		65
British West Indies, Antigua	...		5	
Barbados	...		24	
British Guiana	...		65	
Jamaica	4		65	
St. Lucia	...		2	
Trinidad	...		24	
		4		185
Cuba		4		60
India		203		422
Indonesia		1		21
Mauritius		8		44
Mexico		2		69
Nicaragua		1		6
Pakistan		4		8
Philippines		6		17
South Africa		1		45
United Kingdom		4		17
United States of Ameria, Hawaii		1		31
Mainland		4		39
Puerto Rico		...		18
		265		1068

OTHER COUNTRIES

	Attendance 9th Congress	Total Membership
Afghanistan	1	1
British East Africa	2	6
Ceylon	4	4
Colombia	...	2
Czechoslovakia	1	1
Dominican Republic	...	3
Ecuador	...	1
Egypt	3	3
France	1	2
German Democratic Republic	1	4
Haiti	...	1
Holland	...	4
Indo China	...	3
Iran	1	1
Japan	4	4
Reunion	1	2
Taiwan	...	1
Venezuela	...	7
West Germany	3	5
	287	1123

1956 REGIONAL VICE-CHAIRMEN, I.S.S.C.T.

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Note : Section 5 of Article IV of the I.S.S.C.T. Constitution reads : "A Vice-Chairman shall be elected by each of the various sections within 12 months after each Convention and the retiring Vice-Chairman (who shall be eligible for re-election) shall forthwith notify the General Chairman of the results of such election. In the event of no appointment being made in the terms of this clause, the Administrative Executive shall be empowered to fill the vacancy. The procedure of election shall be decided by the individual sections." The General Chairman , Tenth Congress, is Mr. L.D. Baver of Hawaii, U.S.A.

AGRICULTURAL SECTION

AGRICULTURAL SECTION

Session—Monday, 30th January, 9-15 A.M.

Mr. K. L. Khanna, *Chairman*

The *Chairman* delivered the following opening address:

"It is at once a privilege and a pleasure to be called upon to address a galaxy of Scientists from so many countries and I do so, in all humility, trying as best as I can to place before you some of the aspects that appear to me to need urgent attention. Conditions of cane growing vary considerably in different countries with the result that the local environment and circumstances have determined largely the direction in which research would progress but the essential basic principles underlying it have doubtless remained the same and so also the objectives, viz., the production of greater quantity and superior quality of sugarcane from a unit of land and as cheaply as possible. Because of this fact, it becomes comparatively easy to concentrate on the fundamentals that constitute the basis of research and its execution and such international meets as the present one can serve a tremendous purpose and release unlimited forces of construction that can undoubtedly build an edifice as magnificent as the scientific talent assembled here would like to aspire to, the only pre-requisite being the incessant pooling of scientific knowledge and, where feasible, even resources.

It is sheer waste of effort, energy and money to start in an under developed area from the same point where the more advanced countries commenced decades ago, so that with a body like ours it should be desirable, even essential, that the certain 'do's' and 'don't's' and the 'know how' become available, even unasked, to areas that have land resources suited for the development of the sugarcane crop and the industry dependent upon it. With tailor made varieties to suit practically every conceivable condition of growth both in the tropics and subtropics, it should not be difficult to determine in a reasonably short time what agro-types would suit a new tract and in what manner the best that their makeup offers can be exploited. Likewise, certain basic requirements in the matter of tillage, nutrition, irrigation, plant protection and best utilization of the crop can be delineated to the advantage of the area or the country concerned and an alround standard of efficiency in sugar world production raised.

Another aspect that is worthy of your consideration is the manner in which the necessary collaboration and co-ordination can be ensured not only in different sugarcane countries but also in different research projects involving more than one specialised branch of knowledge. The pattern set by the Sugarcane Research Institutions in most countries would appear to be ideal where a specialised line of investigation is pursued to its legitimate conclusion with the consciousness all the time of its inter-dependence on the other branches of science and its only being a part of the whole and which whole alone can bring about real progress. Agronomical research falls pertinently in this category, for to be fruitful it must lean heavily on physiology, bio-chemistry, entomology and pathology of the crop besides statistics. Lack of complete appreciation of mutual interdependence has not infrequently led to poor or even barren results. A stage would also appear to have been reached where a certain amount of standardisation and rationalisation in technique is called for to ensure valid comparisons of behaviour thereby ensuring progressive efficiency.

VARIETAL ASPECT

The chief problem of the sugar industry remains that of lowering the cost of production of a high quality raw material. This obviously means research in varieties—both breeding and selection ; in soils with regard to their physical attributes, moisture relations, nutrient status and scope for amelioration and responses ; in plant functions to correlate various edaphic and climatic factors with expression of growth, accumulation of sugars and their ultimate synthesis to sucrose ; in agronomy and agrobiology in relation to land use and cropping power. Since variety remains the pivot around which the industry continues to revolve, its early passage through various stages of filtration is a desideratum. Considering further that it takes best part of half a decade for a variety to be selected from its seedling stage and almost a similar period to saturate an area where it may be released for general cultivation, arrangements have to be devised whereby large scale testing over the entire belt can be done adequately and expeditiously so that nothing of value is missed and much that is useless is discarded unceremoniously without much delay. In view of the fact that of all the agricultural improvements, the one relating to varieties has been the most adopted, varietal work both at the breeding centres as also at the testing and subsidiary stations should gain in momentum so that progressive improvements can be maintained in both tonnage and quality factor.

The use of nitrogen-yield index in the breeding of agro-types that would make less exacting demand on the soil would be an important feature in this connection. Similarly, the breeding programme should also aim at developing varieties with outstanding capacity or dry matter accumulation under high levels of nutrients and moisture. Further, for a proper understanding of the quality factor, physiological and biochemical aspects of the leaf tissue with reference to capture of solar energy and its best utilization will need to be studied in detail. High sugar varieties have been found to be associated with higher levels of carbohydrates (both simple sugars and polysaccharides) as also higher moisture contents at all stages of growth and these may suggest early indicator characters for the selection of high sucrose seedlings.

A major challenge to sugarcane workers is the problem of prolonging life of usefulness of proven varieties and discovery of the ratoon stunting disease by Australian workers would appear to have opened out great possibilities in this direction. Although actual breeding for disease resistance has not made much headway, quite effective screening against some of the diseases has been successfully accomplished in a number of countries. In the sub-tropical sugar belt of India, however, due to the appearance of new and more virulent strains of the fungus *Physalospora tucumanensis* Speg., some of the dominant varieties have succumbed one after the other thereby raising a number of vital issues chief among them being, (i) the unpredictable nature of resistance of varieties given out for general cultivation due to sudden appearance of new and generally more virulent strains, (ii) uncertainty regarding periodicity of such changes in the fungus, (iii) edaphic and climatic conditions responsible, and (iv) future varietal policy. Also need a variety go, once it is affected ? On the complete understanding and satisfactory answers to these issues would depend the future adequate servicing of the industry. There is one further point to consider and this relates to the free exchange of suitable commercial varieties from countries that possess near similar conditions of growth. So far, it has been largely a case of one way traffic and it is time that the two way traffic was organised to mutual advantage particularly when intensive breeding programmes have been under way in many countries, resulting in many outstanding varieties.

CULTURAL ASPECT

Next to the selection of variety suited to the climatic and edaphic factors pertaining to a particular locality, the need for preparing an ideal seed bed for high germination and thick density of stand has been generally stressed. The best rotation, as worked out for sugarcane, is a fallow or green manure preceding the crop. With the introduction of mechanical tillage, spacing has come to be determined largely by the need for adjusting inter-row intervals to the type of mechanical implement. Use of mechanical methods of cultivation have led to experiments on the ideal depth of cultivation, as a result whereof deeper planting for heavy yielding deep rooted varieties has been recommended so as to offset effects of the dry period before maturation. Deeper ploughing of soil, aiming at incorporation of a few inches of sub-soil with the surface soil, has been found to result in a deeper rooting habit. The sub-soil being low in organic matter and phosphorus, the addition of cane trash or bagasse and phosphorus, where necessary, converts the mixture of surface soil and sub-soil into a more productive entity. In certain cases, trench planting has also been found useful by way of tapping deeper layers of soil for nutrition and moisture.

The ideal number of buds per sett and number of setts per unit area have been studied with reference to soil conditions with a view to reducing gap intensity in the crop. It seems to be uniformly accepted that three-budded setts do best and are also most economical. The most important problem from yield considerations is the establishment of a dense stand at as early an age as possible. In view of the vegetatively propagated nature of sugarcane, percentage germination achieved in different countries has largely varied. Analysis into the causes of germination failure have led to diverse theories. Thus high glucose and amide nitrogen, optimum moisture content, good undried buds, setts with high nutrient contents and breakdown of natural hormones are regarded as factors favouring rapid germination. In an attempt to improve germination, various types of pre-planting treatments have been resorted to among which may be mentioned soaking in saturated solution of lime with or without magnesium sulphate ; in solutions of various easily available ashes ; in water overnight ; hot water treatment; impregnation of nutrient salts into the setts, soaking in molasses, in various solutions of root promoting hormones, use of setts from top portions and partial drying of cane in the open. More recently, treatment with organo-mercurial fungicides like *Aretan* has been reported to bring about phenomenal improvement in both rate and extent of germination. These fungicides have also been found to improve the tillering phase of growth. The recently introduced Aretan gamma B.H.C. preparation combining the properties of improving germination and termite control, would seem to promise a good deal of improvement in sugarcane agriculture. In Hawaii and Queensland, treatment of setts has found a place in farming routine and similar procedure, adapted to suit local environmental conditions, needs to be made universal in all countries. Another important step would be the development of nurseries to provide seed material at the optimum stage and reinforced through specialised nutrition so as to impart resistance to adverse factors and increase vigour of growth. Likewise the distinction between "mill cane" and "seed cane" and their differential requirements have to be recognised and seedmen or seed plantations dealing with the latter category of material suitably placed in each sugarcane tract to meet its full demand so that the entire crop grown in the area, save that by seedmen under their fostering care, goes to the factory, gets crushed, its earthly remains being consigned to the boiler furnaces thereby eliminating host of inimical insects and diseases.

CROP NUTRITION

The question of optimum requirement of nutrients in the form of fertilizers has attracted considerable attention. The sources of nutrient elements and their forms (organic or inorganic) as also the time of application have been subjects for a good deal of investigation and the same can be said with regard to the uptake of nutrients by the plant in relation to growth and sugar storage. It has been generally agreed that a judicious combination of both organic manure and inorganic fertilizer is the one most conducive to long term maintenance of sugar yields. The early juvenile stage of the plant has been found to be the most active with regard to uptake of nutrient, although a secondary peak is also marked at a later stage in the life cycle. Split applications of nitrogen after more than 6 months from planting do not appear to affect the amount of nitrogen in the leaves at even 18 months age. Press mud, a by-product of the sugar industry, has been getting popular as a source of bulky organic matter in soil management. In view of the restricted availability of phosphates in different soils, application of phosphate to green manure crop has become a common practice so as to ensure a steady supply of readily available phosphorus for the sugarcane crop. Placement of phosphate below the seed has proved an effective method of application. In general, ammonium sulphate, superphosphate and sulphate of potash are the most popular sources of NPK in different countries, although there is an increasing evidence to show that alkaline phosphates perform better in calcareous soils.

Earlier studies in sugarcane nutrition mainly centred on the soil but with the development of foliar diagnostic technique, the idea of plant analysis as a guide to proper fertilization has gained ground. The emphasis in sugarcane nutrition has thus shifted from the soil to the plant. In the ultimate analysis, however, the two would need to go together. Calculations on the basis of NPK taken up in terms of dry matter have revealed the enormous amounts of potash absorbed, in contrast to the low quantities of P and N built up into the body.

In the scheme of plant analysis as a guide to proper fertilization of cane, the indicater tissue reflecting the true nutrient status in the plant has been largely variable in different countries. The ideal tissue is stated to be the third leaf from the top in Mauritius, the leaf with the top most visible dewlap in British Guiana and leaf and sheath numbers 3, 4, 5 and 6 from the top under Hawaiian conditions. Clements went a step further in recognising the ecological conditions and the carbohydrate status of the plant as equally important for its well being and integrated all these facts into his new well known system of crop logging which with slight modifications has not only been increasingly adopted in Hawaii but has stimulated similar work in a number of other sugar countries.

Attempts have also been made at analysing definite tissues of cane under strict conditions of deficiency in respect of individual nutrient elements at various ages of the plant so as to lay down standards for the identification of different deficiencies in the field along with the visible symptoms. Transplanting of healthy canes from the field into nutrient solutions deficient in respect of various elements has been another method for the study of nutrient deficiency. Development of rapid tissue testing procedure is similarly an important land mark in the field of crop nutrition. Though trace elements have been found to improve growth and quality to an extent, no specific deficiencies on a large scale under field conditions seem to have been reported. It is thought that the quantities of these elements contained in the sett and soil along with those available as impurities in irrigation water and fertilizers are commensurate with the needs of the growing crop. Studies have also indicated that continued aerial spraying of these elements improve quality. It has been generally agreed that lack of any of these nutrients in proper amounts predisposes cane to the attack of diseases and pests.

With the availability of radio-active isotopes, the actual function and places of accumulation of nutrient elements have been studied so as to account for all the fertilizers supplied and to adjust the form and time of their application. It has also been suggested on the basis of these isotopic studies that analysis of any single part would not give a clear picture of the nitrogen situation in the whole plant since concentration changed with temperature, age, nitrogen supply and other factors. Very young tissues are hardly found to be affected by deficiency while response increases steadily down to nine or ten leaves, showing that older leaves may be more sensitive indicators than the younger ones. Fall in root temperature lowers leaf nitrogen while fall in air temperature has the reverse effect, thus questioning the validity of the concept of leaf nitrogen status as the guiding factor. Though isotopic studies have greatly advanced the knowledge of plant nutrition, the reliability of such data has not infrequently been questioned on the ground of uncertainties in the matter of tender tissues exposed to radiation revealing the true state of affairs.

The path of N^{15} isotope of nitrogen, the dominant element of plant nutrition, has been traced and it has been found that nitrogen is in a state of flux being moved in a circulatory fashion to all parts of the stool, old nitrogen being exchanged for new. Studies in phosphorus metabolism have gone ahead rapidly, effects of temperature on phosphorus uptake having been analysed. Statistical analysis of the levels of phosphorus found in blades, sheaths and internodes have shown that stalk parts are better indicators of phosphorus fertilisation. Mitscherlich pot tests have also been resorted to by some workers to fix up the nutritional doses for particular soil types. Similarly agro-biological principles such as Wilcox's inverse yield nitrogen law have been invoked from time to time in the analysis of yield potentials of soils and fixation of manurial doses.

On the fundamental side, the effect of total salt concentration and the proportion of each element in the total NPK unit of the medium has been worked out. States of poverty adjustment and luxury consumption of the elements have also been studied for different soils. The balance between the three constituents N, P and K and their interaction in maintenance of high quality and quantity on the basis of the law of limiting factors has been stressed. Nitrogen and phosphorus have been found to be complimentary to one another in their effect on cane growth. Studies in carbohydrate and nitrogen metabolism with particular reference to the various fractions have contributed much towards analysis of aberrations of plant growth and their amelioration.

Rate of photosynthesis or CO_2 uptake from atmosphere is being measured by γ-rays with Cs^{137} as the source with a recording infra-red spectrophotometer. By this means, the influence of various factors on assimilating capacities of leaves is being explored. Studies with P^{32} and C^{14} have enabled analysis of metabolic intermediates of cane leaf. It has been shown that in sugarcane phosphoglyceric acid is not the major carrier of newly fixed carbon and that other compounds are much more richly tagged. Their identification has been thought to be of considerable importance in clarifying the assimilation process in sugarcane.

The use of liquid ammonia as a cheap nitrogenous fertiliser is gaining ground. Granulated fertilizers in place of the powdered form, facilitating application by aeroplane and plough sole, have also found favour. Economy and immediate availability in the centre of synthesis have been the basis of aerial sprays now being largely recommended. Phosphates sprayed on cane leaves from the air stimulate the development of secondary shoots. It has been found that phosphorus is translocated downwards to the stem. Marked response has been recorded to spraying of potash fertilizers as well. Aerial application of nitrogen as urea after the cane crop has closed in is likewise useful, less nitrogen being required than is necessary in soil application. The newer approach to diagnosing nutrient deficiencies and magnitude of responses thereto has been to disperse over the entire environment a large number of simple but well designed experiments and study them in considerable detail with respect to various attributes like tonnage, quality of juice, pest and disease incidence and where feasible even residual effects. Further the belief that quantity and quality do not go together is only half the truth, the other half being that such a relationship is operative only after a certain stage in yield expression has been reached and even at this or a still higher level of production, balanced nutrition with special reference to the soil type concerned, can maintain increments in tonnage with corresponding improvements in juice quality and intensive work in this direction would appear to be called for.

IRRIGATION

On irrigation side, improvements have been effected in various directions. Soil moisture studies with special reference to wilting coefficient, maximum water holding capacity and range of available moisture have enabled maintenance of soil moisture in the upper two-thirds level of the range at all times so as to obtain maximum yields. Moisture content-force curves, representing the suction forces that must be overcome by plant roots if they are to extract water from soil at a particular moisture level, have been useful in this connection. So far as methods of carrying water to fields are concerned, improvements have come about in several distinct stages—from earthenware flumes to wooden ones and then to pre-cast concrete sections. Search for simpler alternative materials for heavy concrete sections brought in paper flumes impregnated with plastic material and of late, these have given place to light aluminium ones which have permitted the lengthening of cane lines indefinitely with cross flumes across the field. These flumes have the advantage of easy movement at will from place to place.

Among irrigation systems, planting of lines in contour has given way to the long line system, with definite advantages over the herring-bone and short line systems. Level ditch system of irrigation is used to some extent on flattened terrain only, inasmuch as ditches occupy considerable area on steep slopes. Soil profile studies of wetting patterns using radio active phosphorus and rubidium have yielded correlations of soil activity with water penetration and helped in characterisation of the efficiency of water distribution under a given set of conditions with regard to soil type, length and slope of a line, volume of water discharged and time of irrigation. With radio-isotopic studies, the herring-bone system was shown to have several outstanding weaknesses. The best distribution was obtained from the line ditch system but it has proved uneconomical. Co^{60} and Cs^{137} are being used as sources of γ-rays for measuring soil moisture at several depths across the main depth, the purpose being to detect gross weaknesses in the water distribution patterns of present systems of irrigation and interpret the results in terms of lengths and grades of lines and volumes of water used.

In the field of irrigation interval control, Das's "day degrees" concept is the first important landmark which led to attempts for measuring the moisture status of soil without undergoing the cost and tedium of soil moisture sampling. An electrical resistance device was developed by Bouyoucos based on the conductivity of plaster of Paris blocks buried in the soil. Recently tensiometers and irrometers have come into use which have a hardy construction and involve lower maintenance costs. Overhead sprinkler irrigation has been attempted from time to time with improvement in efficiency of sprayers. The important advantage of this system has been the overcoming of uneven distribution. When cane plants have grown to a size too large for machine or hand application of fertilizers, aerial application through irrigation water has been resorted to. Portable overhead irrigation, make possible by the innovation of light weight aluminium pipes, is more economical than surface irrigation when 5-6 rounds of irrigation are sufficient to grow a satisfactory crop. There seems to be scope for emergency relief of unirrigated cane by portable overhead irrigation in low rainfall areas. However, this system cannot replace surface irrigation altogether.

Diurnal variations in tissue moisture under different environmental conditions suggested that moisture content of a carefully specified part could be used in the determination of appropriate irrigation intervals. Analysis of plant tissue during the crop cycle has recently led to acceptance of the principle of replenishment based on crop demand and soil supply in preference to static recommendations based on field trials which disregard changing rates of demand and supply as functions of changes in space and time. Use of evapo-transpiration measurements is the most recent development in the determination of irrigation intervals from meteorological data. This consists in finding factors affecting loss of moisture by evaporation and transpiration and enables mathematical computation for each fixed climatic location with no gross variation from season to season. The meteorological approach has the advantage of easy operation with very little cost. In essence, present day irrigation control consists in following the depletion of soil moisture through moisture tension curves, the appropriate tension being used an indicator at the time for irrigation.

There is little doubt that extension of irrigation facilities in countries where they either do not exist or do so only partially would lead to improved varieties, better utilization of manures and fertilizers, more production per unit of land and consequent drop in the cost of cultivation per ton. Attention may also be drawn to other advantages such as better land use, additional and more remunerative cropping, improvement in quality of cane by reduction in the amount of pith and cavity and maintenance of storage tissue in perfect gear besides normalising wide fluctuations that at present occur in the quality factor. One further advantage of great significance to the industry and one which would cut down cost of the raw material substantially, lies in the possibility of rearing ratoon crop with yield as high or better than that of the parent plant crop by enabling timely cultivation, adequate manuring and maintenance of proper crop density in planted rows.

Unirrigated ratoons generally ripen earlier although this seems closely associated with both the variety and the character of the monsoon during September. The fibre content is generally higher and field dryage more pronounced, compared to the plant crop. Irrigation would tend to reduce fibre content , raise extraction and lessen field dryage thereby greatly improving their value.

WEED CONTROL

In the sphere of weed control copper sulphate, arsenate and chlorates have been replaced by the newly developed hormone type of weed killers. These, weedicides, especially effective against broad leaved plants, have been drawn into cultivation practice as pre and post-emergence sprays. With no adverse effect on soil or cane, these have become increasingly popular in recent years. Their range of effectiveness has been found to extend to hitherto uncontrollable grasses of the perennial type.

RIPENING OFF AND BEST UTILISATION OF CROP

The idea that growth should be stopped during the maturation phase so as to divert all energies for accumulation of sugar has been generally realised and irrigations are carefully cut off during the ripening phase of the crop. The optimum period when irrigation should be stopped has been worked out for different soil types. The present planning of crushing programme is chiefly based on a succession of ratoons, early varieties, mid-early varieties and late varieties. It has been established, however, that scheduled crushing in order of maturity as determined in pre-harvest surveys is capable of yielding a higher output of sugar. Foliar application of hormones to increase sugar in cane has been an interesting problem for study in recent years and large scale work is in progress to gauge the commercial possibilities in this direction.

CONTROL OF FLOWERING

The deleterious effect of flowering, both from the growth and sugar point of view has been realised and attempts at checking the same by inhibition of growth at the period of transformation from vegetative to reproductive phase of the growing point by sprays of herbicides or antihormones such as maleic hydrazide have met with considerable success.

HARVEST

Mechanical harvesters have simplified harvesting procedure though care has to be bestowed on avoiding mud and grit which cause considerable difficulty in crushing along with deterioration of cane. Experiments have proved the necessity of minimising the amount of trash in cane supplies to improve purity of juice.

The losses incurred from the slow movement of cane from field to factory through various means of transport have been realised and successful methods worked out for keeping the canes moist so as to cut down losses by inversion. Definite improvement in sugar recovery results from use of this procedure. Possibilities of using various cooling agents would, however, need to be explored.

LINES OF FUTURE DEVELOPMENT

Among promising lines of future development may be mentioned the evolution of newer chemicals and fungicides to further step up germination ; use of isotopic technique in the fixation of manurial requirements with particular reference to relative uptake, accumulation and utilization at centres of metabolic activity ; further exploitation of hormones as agents for improving growth and sugar accumulation ; role of micro-elements and search for newer elements in this category along with their bearing on the yield and quality attributes of crop. Other important lines along which progress can be expected in the near future would consist of isotopic studies on the physiology of tillering and inter-relationship between tillers which may go a long way towards achieving greater intensity of stand. Correlation studies between temperature and sunlight (both duration and intensity) on the one hand and crop growth on the other would similarly have an important bearing on the improvement of cultural practices. Development in instruments for measurement of intensity of radiated light coupled with the use of isotopic technique would also help in a better understanding of stomatal behaviour vis-a-vis photosynthetic mechanism at various stages of the life cycle. Such information would be of great use in the formulation of improved cultural practices. One of the most fascinating lines would appear to be an attempt to accelerate synthesis of sugars and their rapid storage and the causative agents therefor. Likewise high expression potentials and growth restrictions would need to be critically analysed to realise utmost potentialities of a given agrotype. Micro-climatic studies on crop-weather inter-relationships and aerial application of CO_2 into the crop are other lines of work that hold out promise."

The papers contributed by various authors were then taken up for discussion under eight different heads, viz., (i) Growth, (ii) Manurial, (iii) Foliar diagnosis and crop logging, (iv) Irrigational, (v) Cultural, (vi) Weed control, (vii) Juice quality and (viii) General.

GROWTH

Dr. Subba Rao presented the following paper.

Paper

GROWTH CORRELATIONS IN SUGARCANE

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INTRODUCTION

General growth of plant is a composite of the growth of the individual organs of the plant. Healthy and successful development of each of the plant organs leads cumulatively to the well being of the plant as a whole. Unbalanced growth of different plant organs leads to disparity in the outfit and economic produce is to a great extent hampered. On this score, growth correlations, i.e., the relation between organ and organ and as also with the plant as a whole is to be carefully considered in any new venture of crop growth. As a result, study of shoot/root ratio, height/tiller ratio and relations between leaf area and fruit size, yield of fruits and grains have been studied from a long time with reference to each of the new treatments introduced in the plant or soil, to tone up yields.

There has been growing evidence that plants show a consistent relationship between the development of the aerial parts and roots, since the two are interdependent. Evans (1935) found a useful correlation between weight of cane and weight of roots. Chu, Shih and Chao (1949) in Formosa, Roxas and Villiano (1930) in Phillipines, Kulescha (1931) in Mauritius and Stevenson and McIntosh (1935) in Barbados have stressed the relation of shoot/root ratio in sugarcane from time to time.

In oat varieties, yield has been shown to be a factor of leaf vitality by Boonstra (1929). In apples the relations of the distance and direction of fruit from the leaves to their size and composition have been correlated by Haller (1930). Gustafson and Stoldt (1936) showed that by increasing the food producing area, the fruit size was increased considerably though not in the same proportion, showing thereby that fruit size is affected after the setting as well as before. Leaf area in autumn was shown by Sprout, Darrow and Beaumont (1935) to determine fruit bud formation. Jones (1932) showed that an increase in leaf to fruit ratio on ringed branches resulted in increasingly larger fruits on branches, though not in proportion, as the relative leaf area was increased. Harley et al (1932) showed that the principal factor in the initiation of fruit buds in the apple appeared to be the ratio of the amount of foliage to fruit. Thinning practices establishing a relatively high leaf to fruit ratio early in the season were shown to assist materially in ensuring annual production. Chandler (1934) has shown that because fruiting reduced also the leaf surface, it reduced the growth of the trees apparently by a little more than the dry weight of the fruit borne; but when dry weights of wood growth and fruit were considered in proportion to leaf area borne, then fruiting was found to reduce growth by considerably less than the dry weight of the fruit.

Swanson (1941) propounded that in corn, approximate requirement for the production of one bushel of grain was 4000 to 11400 leaves having a total area of 570-3800 sq. ft. Thus for each leaf per stalk functioning during the fruiting period the grain yield was 3.5 to 6 bushels per acre.

Such being the case it was thought that such correlations in sugarcane between leaf area and sucrose and as also between various growth attributes like dry leaves, green leaves, stalk weight and leaf weight at the maturation and harvesting periods would throw valuable light on the relations between these various growth attributes and would point to the criteria affecting quantity and quality of yields in sugarcane. Moreover, it was thought fit to analyse the basic role of leaf area on growth and juice quality in sugarcane on which no literature was available.

It has also been attempted to analyse the part played by leaves in sugarcane as drying proceeds with the onset of maturity. This study became all the more important since no literature on this aspect of the work was available. Results of an experiment conducted in these lines have been detailed in the succeeding pages.

METHODS AND MATERIAL

Three varieties viz. B. 0.10, B. 0.11 and Co. 453 were studied. The samples were collected from the general plantings where all the three varieties were growing in a field of 150′×150′ dimension. The whole field was uniformly manured (60 lbs. N_2+75 lbs. P_2O_5) and cultural operations were also uniform.

Sample from each variety was taken from an area of 1/40th of an acre. The observations were made on four dates, viz., 4th & 17th December, 1953, 16th January and 5th February, 1954, thus covering the maturation phase of the growth of canes. On each date 9 clumps from each variety were selected and only the healthy stalks in a clump were included in the sample. All the observations were recorded on individual stalk basis except cane weight and juice weight which were recorded on clump basis and the values subsequently calculated on stalk basis. Correlations and regressions have been struck between the various characteristics to find out the possible relation between themselves and more so with the economic attributes to get an insight into the criteria for yield and quality.

EXPERIMENTAL FINDINGS

(*a*) *Correlations*

Sucrose percent and stalk weight when correlated with the various growth attributes like weight of juice, weight of stalk, number of green leaves, dry weight of green leaves, number of dry leaves, and total area of green leaves showed some interesting results.

Weight per stalk was outstandingly correlated with most of the characteristics except percentage sucrose. Amongst the different characters under consideration, weight of juice extracted per weight of stalk showed as high a positive correlation as 0.927. Next in order came the relation of the number of dry leaves to weight per stalk with a correlation coefficient of 0.6988 while total area of green leaves showed a significant correlation though at a lower level with a value of 0.3945. Dry weight of green leaves and number of green leaves per stalk also showed a positive correlation at a lesser level with weight per stalk (Table I).

TABLE I

SHOWING CORRELATION COEFFICIENTS BETWEEN VARIOUS CHARACTERS OF SUGARCANE PLANT.

	Juice weight per stalk	Sucrose percentage	Dry weight of green leaves per stalk	Total area of green leaves per stalk	No. of green leaves per stalk	No. of dry leaves per stalk.
Cane weight per stalk.	0.9270*	—0.0868	0.3936**	0.3945*	0.3041**	0.6988*
Juice weight per stalk.		—0.1104	0.2939*	0.3910*	0.2715*	0.4482*
Sucrose percentage			—0.2520**	—0.0960	—0.1956	—0.0782

*Significant at 1% **Significant at 5%

Weight of juice also followed closely the relationship exhibited by weight of stalk in that, all the correlations struck attained a high level of significance. Weight of juice per stalk was best correlated with the number of dry leaves with a value of 0.4482. Next in order came the total area of green leaves per stalk with a value of 0.391. Number of green leaves and dry weight of green leaves though significantly positively correlated with weight of juice showed lower values of 0.2715 and 0.2939 respectively.

While this was true of weight of stalk and weight of juice, the correlation coefficients of sucrose with most of the characteristics were negative and non-significant except in the case of dry weight of green leaves per stalk wherein it showed a negative significance though at a lower level. Weight of juice, weight of stalk, number of green leaves and number of dry leaves all showed negative non-significant correlation (Fig. 1).

(*b*) *Regression*

Regression values when struck between the various related attributes showed the following trend. Weight of juice was positively related with all the other characteristics namely weight of stalk, number of green leaves, number of dry leaves, dry weight of green leaves and total area of green leaves though the significance of the latter two was at a lower level (Table II).

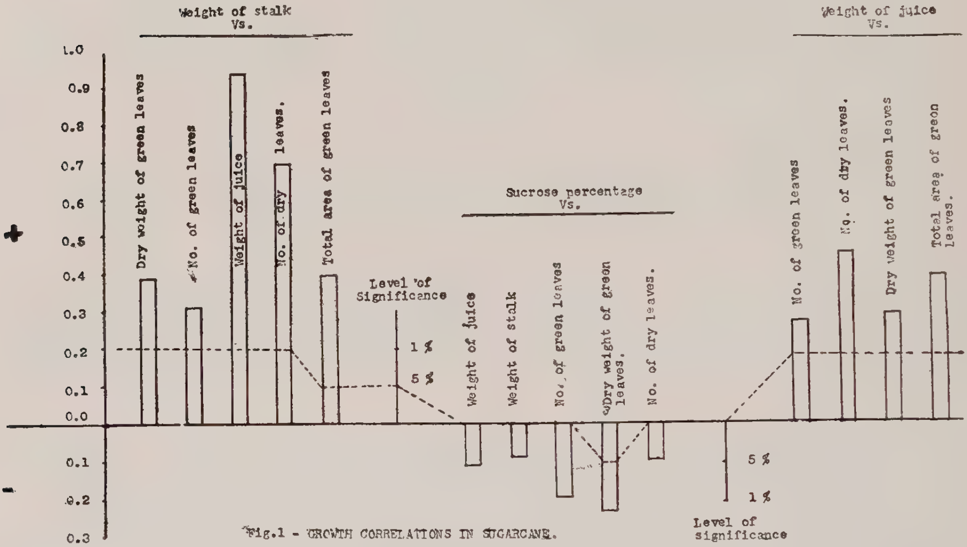

Fig.1 - GROWTH CORRELATIONS IN SUGARCANE.

Sucrose on the other hand as in the case of the correlation coefficient was negatively related with all the characteristics namely weight of juice, weight of stalk, number of green leaves, and dry weight of green leaves, attaining the level of significance at a lower level only in case of the latter.

Number of green leaves though positively related with weight of stalk did not attain the level of significance, whereas number of dry leaves showed a positive and highly significant relation. But dry weight of green leaves again showed a non-significant positive correlation. Highest value for regression for the whole experiment was however attained by area of green leaves with weight of stalk (Fig. 2).

TABLE II

SHOWING REGRESSION COEFFICIENTS BETWEEN VARIOUS CHARACTERS OF SUGARCANE PLANT.

	Weight of Juice	Sucrose	No. of green leaves	No. of dry leaves	Dry weight of green leaves	Area of green leaves
Weight of stalk in ozs.	0.543201*	—0.007207	0.059326	0.211730*	0.468039	41.685199*
Weight of Juice in ozs.		—0.016952				
Number of green leaves.	0.8159*	—0.165894				
Number of dry leaves.	0.8670*					
Dry weight of green leaves in gms.	0.1449**	0.021972**				
Total area of green leaves in sq. cms.	0.002167**					

*Significant at 1% **Significant at 5%.

DISCUSSION

The correlation studies showed that the yield in terms of weight of stalk and weight of juice extracted from it had a significant positive correlation with all the growth and physiological attributes whereas sucrose was not at all governed by any of these factors except the dry weight of green leaves per stalk. These correlations suggested that with an increase in weight of stalk there would be a positive increase in juice weight extracted from it whereas percentage of sucrose would decrease though not significantly. Number of dry leaves per stalk, dry weight of green leaves, number of green leaves and total area of green leaves all seemed to significantly improve cane weight per stalk or in other words, leaf formation, its area and its driage seemed to have a positive influence on the yield of canes.

Against juice weight per stalk, sucrose again showed a negative non-significant correlation meaning thereby that with the increase in the amount of juice extracted per stalk percentage of sucrose would tend to go down, whereas all leaf characters again showed a positive correlation with juice weight per stalk. Juice weight per stalk and cane weight per stalk were positively and significantly improved by the same set of characteristics.

Sucrose exhibited a negative relationship with all the characteristics of growth, only the relation between dry weight of green leaves showing a definite trend with percentage sucrose. Amount of leaf tissue formed seemed to have a depressing influence on percentage sucrose.

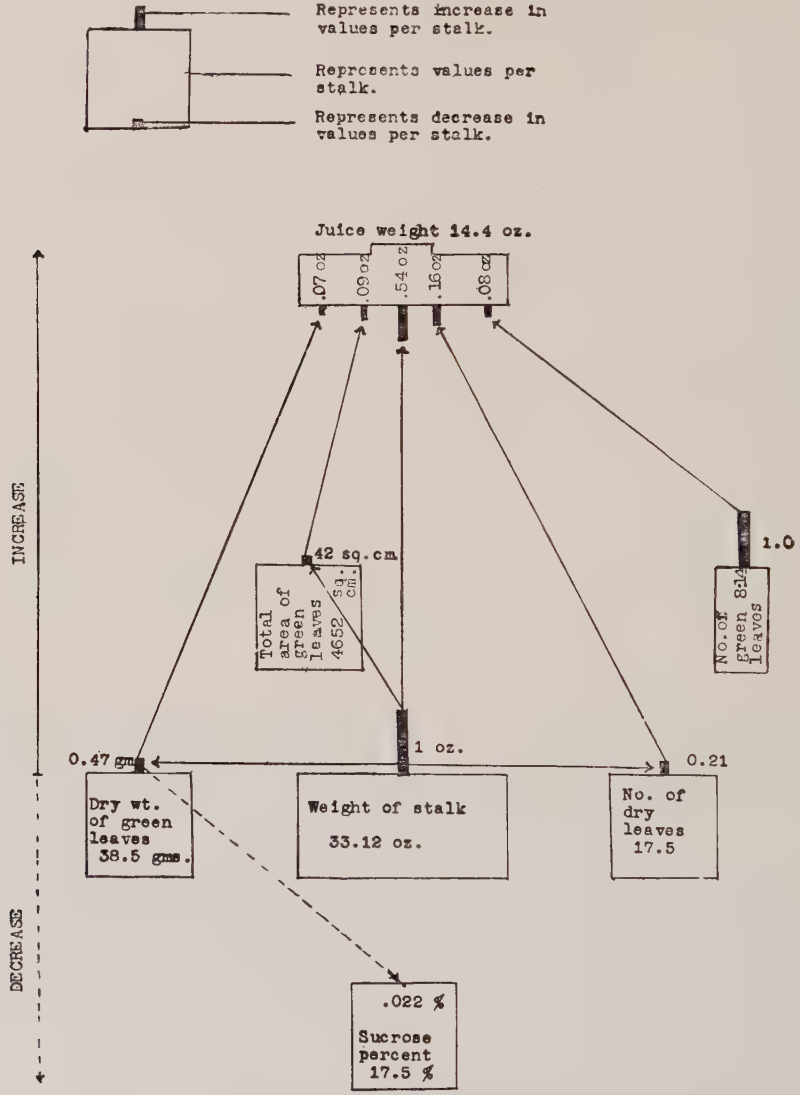
Represents increase in values per stalk.
Represents values per stalk.
Represents decrease in values per stalk.
Juice weight 14.4 oz.
.07 oz
.09 oz
.54 oz
.16 oz
.08 oz
INCREASE
DECREASE
42 sq.cm.
Total area of green leaves 4652 sq. cm.
1.0
No. of green leaves 8.14
1 oz.
0.47 gms
0.21
Dry wt. of green leaves 38.5 gms.
Weight of stalk 33.12 oz.
No. of dry leaves 17.5
.022 %
Sucrose percent 17.5 %

Fig. - 2. DEPICTING THE RELATIVE INFLUENCES OF THE VARIOUS GROWTH CHARACTERISTICS OVER EACH OTHER AS CALCULATED FROM REGRESSION VALUES.

Regression coefficients indicated that weight of juice was significantly increased at least by 50 percent with a unit increase in weight of stalk, whereas with an increase in green leaves by one unit, weight of juice was increased to a greater extent (80%). But dry leaf number had a much superior effect in that it increased juice weight by 86%. But dry weight of green leaves and total area of green leaves did not seem to have the same influence as the other three characteristics on weight of juice.

Whereas this was true of the weight of juice the regression coefficients of the various growth characteristics against sucrose were all negative and non-significant except for the dry weight of green leaves which alone showed a negative significant correlation though at a very low level. The natural surmise would be that change in weight of stalk would have little effect on sucrose percentage and that sucrose percentage would decrease to that extent with an increase in weight of stalk. The same relation holds good in case of weight of juice and number of green leaves in that the sucrose percentage decreased to the extent of the regression coefficients by an increase in the amount of juice extracted or with an increase in the number of leaves. Whereas all these relationships of sucrose were not significant the sucrose percentage decreased significantly with an increase in the dry weight of green leaves.

Number of green leaves tended to increase by 0.059326 with an increase in unit weight of stalk. But number of dry leaves proned to increase significantly by 0.211730 with a unit rise in weight of stalk. Dry weight of green leaves showed tendency to increase by 0.468039 with a unit rise in weight of stalk though not significantly. But the area of leaves tended to increase enormously by as much as 41.685199 with a unit increase in weight of stalk.

These results were in consonance with the known basic facts of plant growth. General growth was closely correlated with the growth of the component organs whether it was growth in form, size or weight and as such we have found in sugarcane also these growth laws being rigidly followed. On the contrary both the correlation and regression coefficients pointed out that the changes in sucrose value did not depend upon these growth characteristics at all and in fact a negative relation was established. The well known fact that quantity and quality, namely tonnage and juice quality, could not go together has been once again made clear by these studies. Plant breeders have rarely been successful to evolve a variety which would combine both yield and tonnage. They seem to be divergent characteristics. It seems we have to strike a balance between these two factors in selection of varieties or treatments for economic crop production. Apart from this, the green leaves alone seem to have some significant effect on sucrose, the higher the weight of green leaves at the moment the lesser the sucrose. This means that driage of leaves has some thing to do with this character. Might be that when the active green leaves begin to dry, concomitant favourable changes are brought about in the internal metabolism of the plant. On the contrary, continuance of green leaves on the stalk seems to be detrimental from the point of view of sucrose.

This fact has further significance as could be made out from the tables that dry weight of green leaves is the one common character which shows a significant correlation and regression coefficient with all the characteristics, thereby indicating that driage of leaves or dry weight of green leaves holds a balance or the key to quantity and quality of yields in sugarcane agriculture.

Time, season and age seem to have of course a greater impact on sucrose than any of the external characters. The results of this experiment seem to be valuable as a guide, in the future planning of experiments on the indicator characteristics for quality and quantity of sugarcane yields.

SUMMARY AND CONCLUSIONS

1. There was a significant positive correlation of cane weight with juice weight, number of green leaves, total area of green leaves, dry weight of green leaves and number of dry leaves.
2. Juice weight per stalk showed significant positive correlation with number of green leaves, total area of green leaves, dry weight of green leaves and number of dry leaves.
3. Sucrose percentage showed significant negative correlation with dry weight of green leaves. It was negatively correlated with cane weight, juice weight, number of green leaves, total area of green leaves and number of dry leaves though the correlation was non-significant even at 5% level.
4. Weight of juice was influenced most by number of dry leaves followed by number of green leaves, weight of cane, dry weight of green leaves and total area of green leaves in the descending order.
5. Unit increase in dry weight of green leaves significantly decreased sucrose by 0.0219 percent.
6. With increase in weight of stalk, number of dry leaves as also area of green leaves increased significantly.
7. General growth was closely correlated with the growth of component organs as also juice weight. On the contrary changes in sucrose values did not generally depend upon the growth characteristics.
8. Dry weight of green leaves was significantly correlated with all the three characters, viz., weight of cane, weight of juice and sucrose percentage and thus indicated that dry weight of green leaves may be holding a balance or the key to quantity and quality of yields in sugarcane.

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Paper

STUDIES ON TILLERING OF SUGARCANE

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INTRODUCTION

The characteristics of tillering of sugarcane plant had been very interesting to the planters as well as to the agronomists of sugarcane. Experience reveals that the number of tillers produced per stool has greatly determined the number of millable stalks per stool at harvest. It is the main factor determining the yield of millable canes per unit of area. Furthermore, the time, angle and depth of emergence of the tiller are closely related to the fate of the tiller in its later development.

In the previous reports (2, 3, 4), the authors noticed that the mortality of the tillers caused by insect pests depends very much on the time of emergence. This is especially true in the case of sugarcane borers. The newly emerged tillers with slow elongative growth are usually inflicted by top borers such as *Eucosma schistaceana* Snell., *Proceras sacchariphagus* Bojer, and *Diatraea venosatus* Walk. The elongative growth of the newly emerged tillers is determined again by the angle of emergence formed with the ground surface and the depth beneath the soil surface by the tiller itself. These factors, the time, angle and depth of emergence, have a decided effect on the survival of the tiller which eventually determines the number of millable stalks developed per stool throughout the growth cycle.

Since the profuseness or scarceness of tillers of a variety of sugarcane had aroused much concern in sugarcane agronomists, it seems important to know whether it is caused by cultivation methods or heritable factors or both. It is of course, the fertility of soil of the sugarcane field that has played an important role both in formation and survival of the tillers of the stool. Secondly, the death of tillers approximates two out of three, the percentage of mortality rate being as high as 60 to 70 percent in Taiwan. The degree and reason of the exact causes are still not well understood. A careful study would reveal as to whether the death was caused physiologically by growth competition, or physically by mechanical injury or insect injury. And thirdly, the causes of the lack of vitality of some of the weaker tillers are physical inadequacies such as lack of space, or location above the soil surface ; or the formation of stalk roots is too scanty and too slow. Until all these questions have been correctly answered, the puzzle of the life and death of the tillers of the sugarcane plant is not solved and the cultural practice of sugarcane is an empirical technique and not a science.

During the present decade, studies on tillering of the sugarcane plant had been carried and were still continuing extensively in the recent years. The present report summarises the experimental results of the up-to-date study. It is hoped that some of the information may fill the gaps which long had been neglected or at least lacking in the literature on the sugarcane plant.

METHODS AND MATERIAL

Precaution was taken to avoid the effect of earthing-up on the emergence of the tillers. So there was no hilling during the tillering period. The seed-pieces of the September-planting were planted with 1-eyed setts. As a rule, the setts were naked or visible upto three months after planting, so that the original form of tillering was maintained as much as possible. In case the growth of the tillers of the whole stool was fast enough and most of them grew homogenously to a height of 30 to 40 centimeters, a quarter of spade of soil was filled in the centre of the stool to promote the production of stalk roots or the latest tillers.

Earthing-up was made in May ; most of the tillers of the stool developed into millable stalks, forming 30 to 50 centimeters in length of internodes for each stalk. Optimum conditions for growth were provided. The field was irrigated and drained whenever necessary.

1. *Observational plot.* At least twenty varieties for each type of tillering were planted with usually twenty 1-eyed setts for each row which is 8 meters in length. There were three rows for each variety with two replications. The use of the observational plot was mainly for general observations on the characteristics of the various types of tillering of the sugarcane plant. Two stools of the representative variety of each type of tillering were selected to measure monthly the angles of emergence of the first formed tillers, IA and IB, the two lowest tillers of the stool representing the changes of the emerged angles of all members of the stool.

2. *Dissecting plot.* Thirty two one-eyed stools were planted in four rows each for representative types of tillering. Each row was 8 meters in length and had eight stools. It was decided to study weekly the date of emergence and death of the tillers for every stool with detailed records on the number of leaves produced and growth in length for each tiller.

One representative stool for each type of tillering was dug up monthly with roots and then washed of all the soil. The green leaves were removed separately for each tiller with a sharp scissors from the dewlap. The area of each leaf blade was measured by dividing the upper part of the leaf blade

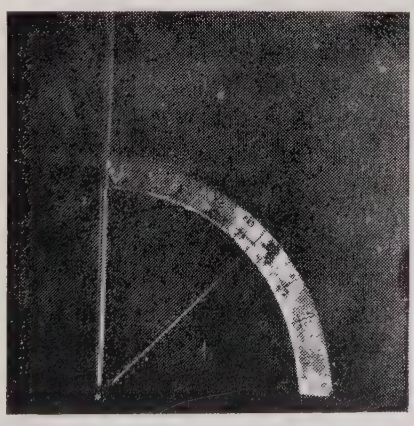


Fig. 1 : Protractor with a movable pointer on the scale to show corresponding angle.

as an isosceles triangle and the lower part as a rectangle. The angle of emergence of each tiller was measured with a specially designed protractor. After all these records had been taken, the stool was dissected carefully according to the dates of emergence of the tillers which were tagged with labels marking the dates from the first week onwards. After measuring the length, all the sheaths were removed and the stalk-roots were counted for each tiller. The volume of stem formed by each tiller was measured by method of water displacement.

The stool dissection was made monthly from October, one month after planting, to May of the next year, *i.e.,* over the entire tillering period.

RESULTS

TYPES OF TILLERING

The types of tillering of sugarcane were first noticed by the authors in 1948 in the fields of the second-year seedlings bred by this Station, numbering more than two thousand. All these seedlings were planted two to three months ago. It was found that the types of tillering varied with the angles of emergence of the tillers. Some of the tillers emerged from the soil surface with an angle less than 20 degrees, some even less than ten degrees, simply laying down on the ground, and some with 60 degrees while some with 90 degrees, standing vertically on ground. Careful observations revealed that each variety had its own characteristic type of tillering if the stooling habit of each variety was studied. Since then the observations were continued every year during the tillering period. Four types of tillering were described by the first author (1)(Fig. 7) and type of tillering became one of the items of our field record for the second-year seedlings bred every year by this Station. More than ten thousand varieties of sugarcane have been studied so far ; no exceptional type of tillering has been found. They are :

1. *Cup-shaped tillering.* Varieties of this type of tillering or stooling are usually upright growing varieties of sugarcane. They are usually deep-rooted and grow rather slowly during the early period of tillering. The mother stalk of the stool is usually erect forming two right angles with the soil surface while those of the first-formed tillers are extended centrifugally from the ground to form an angle from 60 to 80 degrees (Fig. 2). Stool of this type is compact and dense resulting in the homogenous development of almost all tillers of the stool. The predominance in growth of the mother stalk disappears at the middle of the tillering period. The number of tillers per stool is usually numerous and most of the millable stalks of the stool are developed from the mother stalk and from primary tillers. Very low percentage of millable stalks comes from secondary tillers. Most tillers of this type produce stalk-roots early.

2. *Bowl-shaped tillering.* Varieties of this type are usually excellent stooling and covering varieties of sugarcane. Both the mother stalk and the first-formed tillers possess a slanting position forming angles of 40°-60° with the ground

surface although the angle of emergence of the mother stalk sometimes is as large as 70 to 80 degrees. (Fig. 3).

The stool of this type of tillering extends over larger space than that of the cup-shaped tillering. The interspace, therefore in this type of tillering usually closes in as early as three to four months after planting. The prolific and vigorous stooling of this type of tillering makes an attractively good beginning. The predominance in growth of the mother stalk lasts mostly till the middle of the tillering period which is usually beginning of closing-in period.

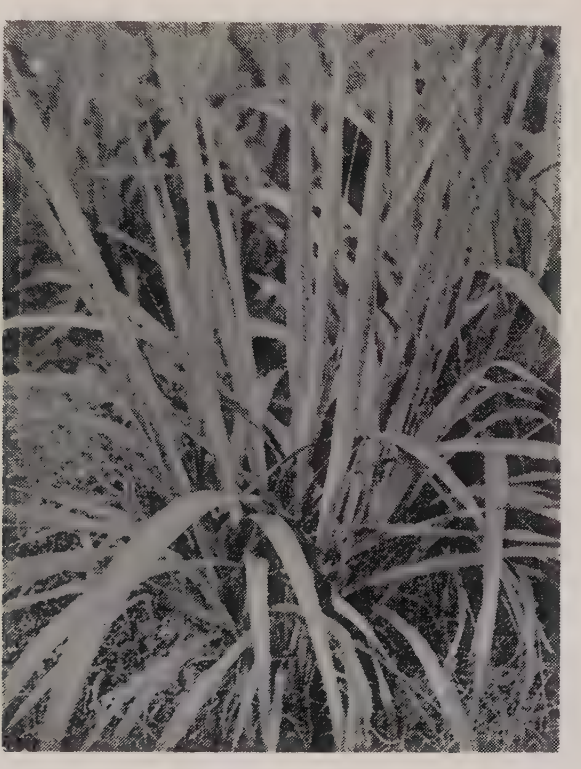


Fig. 2 Cup-shaped-tillering at age of 3½ months (P. T. 48-1).

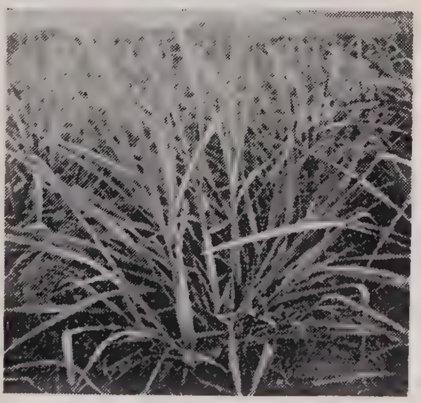


Fig. 3 : Bowl-shaped tillering at age of 3½ months (P. T. 52-1).

3. *Dish-shaped tillering*. The characteristic of this type of tillering is the sprawling growth habit. Varieties of this type are usually recumbent in the early stooling period. Both the mother stalk and the first-formed tillers form certrifugally

very acute angles from O-25° with ground surface, most of them simply lying on the ground with the two lowest primary tillers, 1A and 1B, in three directions (Figs. 4-5). It seems that they lack phototropic response and

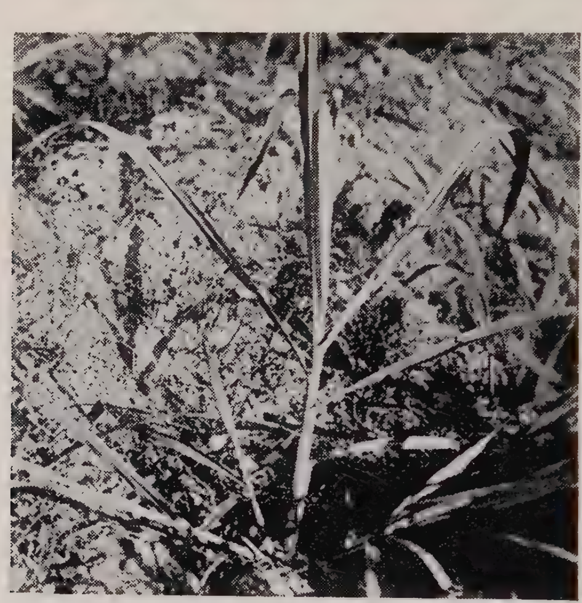


Fig. 4 : Dish-shaped tillering at age of 2 months (P.T. 48-87).

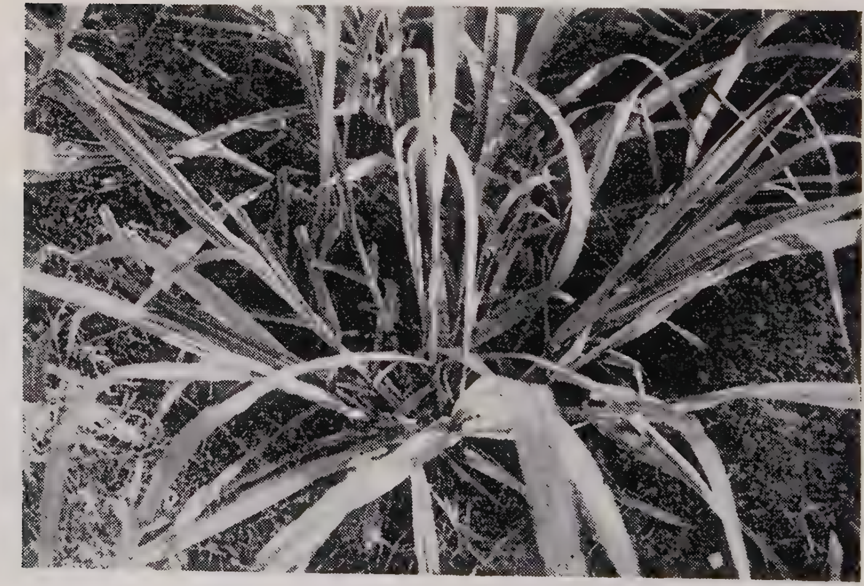


Fig. 5 : Dish-shaped tillering at the age of 3½ months (P.T. 48-87).

until the middle of the tillering period, the sensitiveness towards the sun light of the tips of the mother stalk and those of the tillers gradually increases resulting in the raising up of the tips of all the members of the stool. However, this movement is slow and the complete erection of all the members of the stool occurs usually at the end of the tillering period.

Varieties of dish-shaped tillering are usually shallow-rooted. The early disappearance of the predominance in growth of the mother stalk hastens the formation of tillers.

4. *Fan-shaped tillering.* Fan-shaped tillering is characterized by the

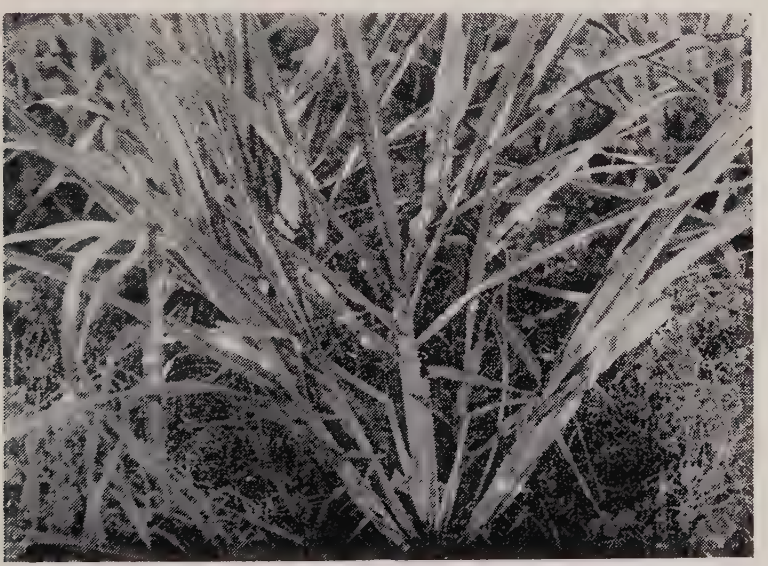


Fig. 6 : Fan-shaped tillering at age of 3½ months (P.T. 43-52).

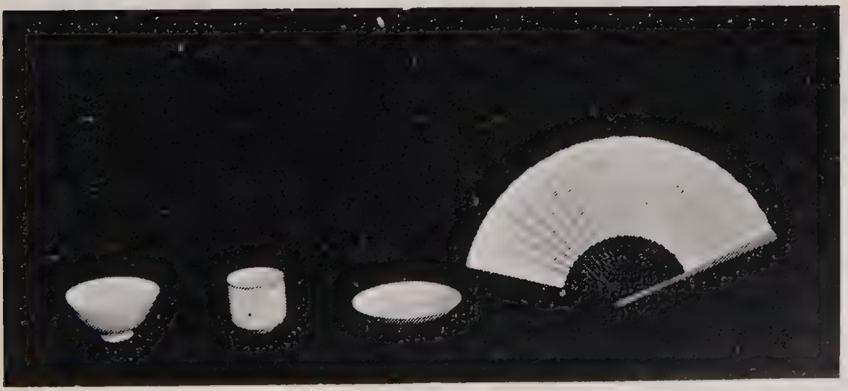


Fig. 7 : Mode of the four types of tillering of sugarcane ; from left to right : bowl-shaped, cup-shaped, dish-shaped and fan shaped.

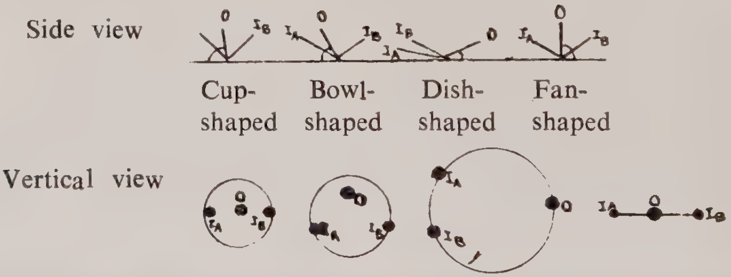
emergence of the members, both the mother stalk and tillers, of the stool in one plane. The mother stalk of the stool is usually erect while the two lowest primary tillers emerge from the ground surface with an angle of 40 to 70 degrees. Stool of this type of tillering remains fan-shaped till the middle of the tillering period but is modified later as the secondary tillers emerge. The emergence of the secondary tillers is usually later than in other types of tillering. The mother stalk of the stool leads in growth among its members and remains predominant till the end of the tillering period. The strong predominance in growth of the mother stalk has caused fewer and weaker tillers to emerge.

Cup shaped tillering may exhibit fan-shaped arrangement during the very early 2-to 4-tillered stage which however changes immediately as more tillers emerge.

The four types of tillering iust mentioned exist only at 8 to 10 tillered stage, sixty to one hundred twenty days after planting. During this period, most of the emerged tillers of the stool retain their original angles displaying typically the type of tillering to which the stool belongs. With the exception of early high-hilling of soil and dense planting, one can recognize the type of tillering readily on close field observation.

The size of space occupied by the stool and the angles of emergence of its members are shown in the following diagrams :

Diagram I :



It was an established fact (2) that the slantingly emerged tiller grows much slower than an upright one if both appear at the same time in the same stool. Should the slantingly emerged one be the mother stalk, then it sends out new tillers instead of increasing in length. The greater the degree of the angle of emergence the faster is the growth linear and slower and fewer are tillers produced. It is true of the reverse as well. The dish-shaped tillering occupies the largest space and produces tillers prolificly but the members grow in length slowly, while the fan-shaped tillering with least space under a stool tillers slowly but the few tillers grow in length rapidly.

As a result of growth, the angles of emergence of the tillers enlarge with the age resulting in the gradual change of the various types of tillering till the development of an erect stool.

From Table I, it will be seen that with the exception of fan-shaped tillering which forms erect stool as early as February, most of the other types of tillering begin to form erect stools in April and complete the process in May.

As a rule, the dish-shaped tillering is usually the last to complete the stooling. Consequently, the millable stalks formed by this type of varieties are always shorter.

TABLE I

CHANGES IN THE ANGLES OF EMERGENCE OF THE MOTHER STALK AND OF TWO LOWEST TILLERS DURING THE PERIODS OF TILLERING AND THE DEVELOPMENT OF THE VARIOUS TYPES OF TILLERING INTO AN ERECT STOOL.

Months	Cup-shaped P.T. 51—11			Bowl-shaped P.T. 51—19			Dish-shaped P.T. 51—406			Fan-shaped P.T. 51—415		
	O	IA	IB	O	IA	IB	O	IA	IB	O	IA	IB
Nov.	80	70	70	80	47	50	84	18	23	85	50	40
Dec.	70	52	52	89	49	49	80	42	30	85	56	62
Jan.	80	62	62	75	52	55	75	38	40	90	58	68
Feb.	65	65	62	90	50	50	62	50	48	81	72	75
Mar.	80	65	63	75	50	60	70	65	48	90	80	80
Apr-	80	75	84	83	83	80	78	78	81	90	80	85
May	85	82	84	90	82	80	84	85	82	90	88	88

Since the erect habit is necessary for the growth in length of any member of the stool, it is apparent that the completion of an erect stooling means that all the members of the stool are ready to grow if the climatic conditions are favourable. The early formation of an erect stool in fan-shaped tillering varieties starts stem-formation two months earlier than in other types of tillering. The canes form internodes instead of more tillers. As a result, the varieties of this type usually possess fewer tillers than those of the other types of tillering, if the planting furrow is not kept open as late as May. The other types of tillering usually complete their stooling in April and longer period for tiller production results in more tillers per stool. This is further proved by the monthly measurement on the angles of emergence of the members of the whole stool (Table II).

The information on the change of angles of emergence of the members of the stool is obviously a good guidance for cane cultivation. It is especially important to determine the reasonable time to fill the planting furrow, or final earthing-up where hilling is practised.

TABLE II

THE FREQUENCY OF ANGLE OF EMERGENCE OF THE MEMBERS OF THE STOOL DURING THE PERIOD OF TILLERING AND THE DEVELOPMENT OF THE VARIOUS TYPES OF TILLERING INTO AN ERECT STOOL

		Ranges of emerged angles (Degrees) :							
Months	Varieties	0-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90
Nov.	P.T. 50—62		1	1	1	6	5	1	—
	P.T. 50— 2		—	1	—	4	2	1	—
	P.T. 51—11		1	—	1	—	4	—	1
	N : Co 310		—	—	1	2	3	—	—
Dec.	P.T. 50—62	3	—	3	2	2	3	1	—
	P.T. 50— 2				4	5	11	4	1
	P.T. 51—11				6	3	10	6	1
	N : Co 310				—	15	12	1	—
Jan.	P.T. 50—62	2	1	4	3	4	3	1	—
	P.T. 50— 2				2	7	13	6	1
	P.T. 51—11				2	5	14	8	3
	N : Co 310				—	15	12	1	—
Feb.	P.T. 50—62			2	5	10	6	3	—
	P.T. 50— 2				—	4	14	9	2
	P.T. 51—11				1	5	11	6	4
	N : Co 310				1	22	26	9	2
Mar.	P.T. 50—62				2	11	13	6	2
	P.T. 50— 2				—	2	17	4	—
	P.T. 51—11					—	15	17	3
	N : Co 310					6	24	9	2
Apr.	P.T. 50—62					2	6	15	3
	P.T. 50— 2						7	4	3
	P.T. 51—11						1	20	5
	N : Co 310						7	42	3
May	P.T. 50—62							7	7
	P.T. 50— 2							7	1
	P.T. 51—11							11	9
	N : Co 310							12	22

The type of tillering is heritable. Progenies of POJ2364 are usually of dish-shaped tillering while those of P.T. 43-52 have fan-shaped tillering in majority. Environmental conditions such as temperature, water and light etc., can not change it. The only factor which changes the types of tillering tremendously is the deep covering of soil in the early period of tillering, modifying physically the emerged angles of the tillers as well as of the mother stalk. Dense planting also changes the type of tillering greatly.

Mortality of tillers.

The mortality of the tillers is highly related with the types of tillering (1,2).

It is highest in dish-shaped tillering and lowest in cup-shaped tillering varieties. The fan-shaped and bowl-shaped tillerings are intermediate. The main factor which determines the mortality of the tillers is their elongative growth. And this again is determined by their angle of emergence. It was found that most of the dead tillers throughout the tillering period were the weak and slow-growing ones. The slow growing tillers are apt to be preys of the top borers of sugarcane becoming "dead hearts" of the stool.

Besides the depth of the bud location, the time of emergence, the number of tillers which emerge at a time and the production of stalk roots have also physiological effects on the elongative growth of the tillers, if they are grown under the same climatic conditons.

In the monthly dissection of stools of four varieties of sugarcane, some very interesting results were obtained as shown in Table III.

TABLE III

THE MORTALITY RATE OF TILLERS OF FOUR STOOLS OF SUGARCANE IN DIFFERENT AGE GRGUPS DURING THE PERIOD OF TILLERING.

	Age of tillers (Days after planting) :					
Months	30	60	90	120	150	Total
Nov.	—					
Dec.	4	1				5
Jan.	4	8	1			13
Feb.	8	10	20	1		39
Mar.	23	6	15	10	4	58
Apr.	19	3	9	12	8	52
May	31	5	9	11	8	64
Total	89	33	54	34	21	231
%	38.25	14.28	23.38	14.72	9.47	100.00

Two notable results are revealed from this study. First there were seventy six per cent of death which were from 30 to 90 days after emergence, showing that most of the tillers die at the age of three months or less. Secondly, ninty-nine percent of the deaths was caused by top borers, mostly *Eucosma*, *Proceras* and *Diatraea*.

The death of tillers of the stools during the tillering period caused by sugarcane borers has been reported as one of the two major factors (2,4) in Taiwan, but on careful dissecting studies, we found that the main cause is the infestation by sugarcane borers. Physiological weakness, such as lack of stalk roots and poor elongative growth only accentuate the attack by sugarcane borers.

On analysing the dates of emergence of the dead tillers, it was found that the highest percentage of the dead tillers emerged in March and April (Table IV) :

TABLE IV

THE NUMBERS OF EMERGENCE AND DEATH OF THE TILLERS OF FOUR STOOLS OF SUGARCANE DISSECTED MONTHLY AND THE PERCENT DEATH OF THE TILLERS EMERGED IN VARIOUS MONTHS DURING THE TILLERING PERIOD.

	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.
Nos. of emergence	80	265	204	115	69	44	13	18
Nos. of death	14	66	55	21	18	26	11	5
Per cent of death	17.5	25.2	27.0	18.2	26.1	59.1	84.6	27.7

Some of the late tillers attacked by the sugarcane borers become growth "laggards" at the end of the tillering period and usually die out or are simply cut off by the farmers prior to earthing-up.

In order to obtain more detailed information concerning the mortality and the time of emergence of tillers, Diagram II was sketched. It shows precisely the order of the tillers and the dates of emergence and death. From the diagram it was found that, without exception, the October-emerged tillers, mostly the lowest-emerged tillers designated as IA and IB in Table I, form the main mother axes from which the members of the stool originated at the end of tillering period. The advantage of lower position of emergence of these tillers causes early formation of the secondary order of tillers of which the dates of emergence were generally November and December. Close examination of the dates of emergence of the living tillers and of the survivals showed that 66.7% of the total tillers of the stool emerged from these two October-formed tillers, thus showing the primary importance of these two lowest tillers so far as the formation of millable stalks of the stool is concerned. Late tillers, formed in January, February and March, increased prolificly in March but disappeared rapidly in May. If all of these late tillers could be suppressed by means of cultivation measures prior to emergence, better and stronger growth of the surviving ones would be anticipated. Furthermore, this would result in the early start of homogenous growth of the members of the stool which is both important in elongative growth of the stool as well as the yield per hectare as a whole.

Notes on Diagram II :

1. Solid line with O designates mother stalk.
2. Solid line designates primary tillers, or tillers of first order.
3. Broken lines :
    - a. ....secondary tillers, or tillers of second order.
    - b. ....tertiary tillers, or tillers of third order,
4. Numbers at the end of each line designate the sequence of emergence of the tillers.
5. "X" at the end of each line designates the death of the tillers.
6. The dates designate the dates of emergence.

Physiologically, the late tillers were usually thrust in poor space and the

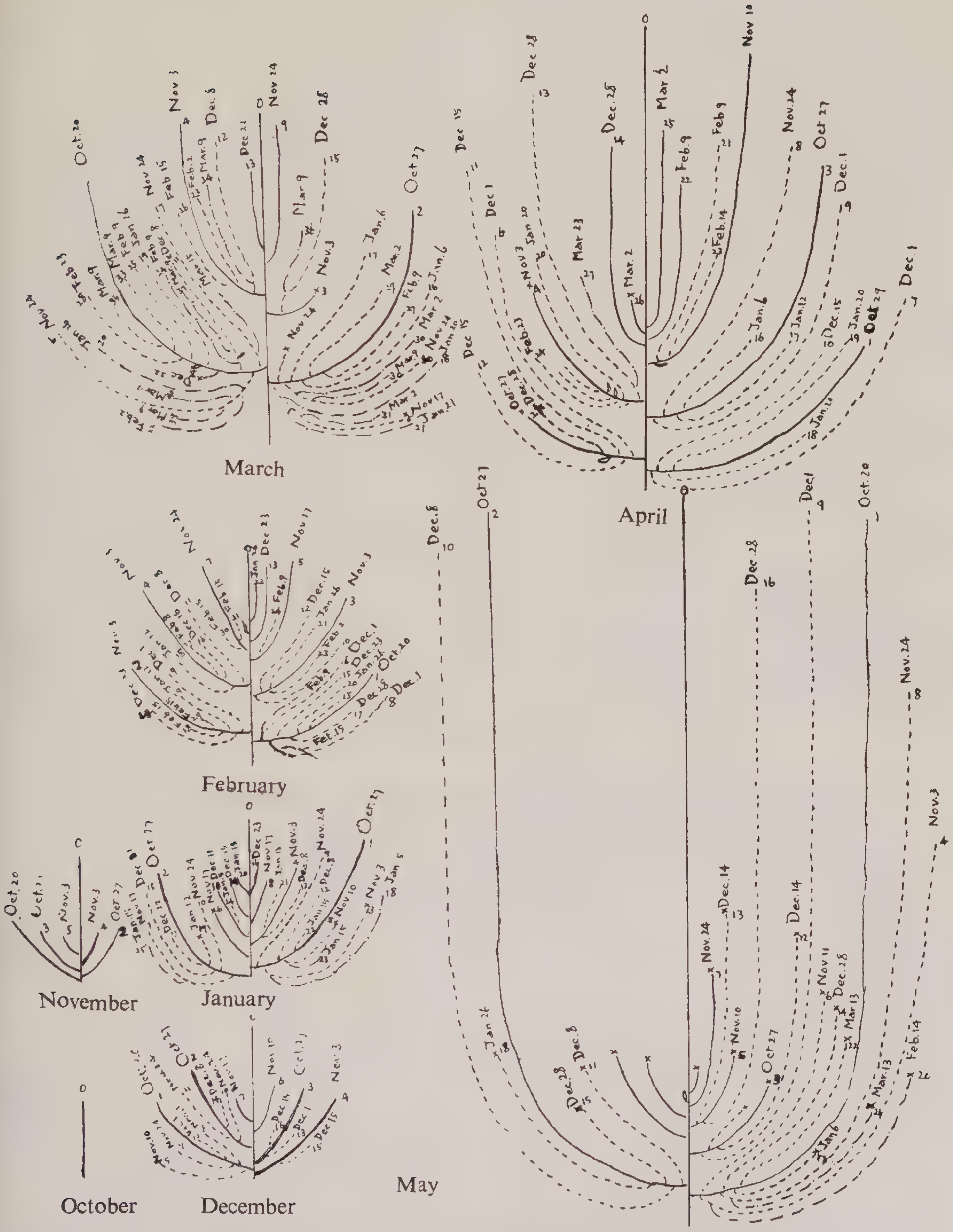

March
April
February
November
January
October
December
May

Diagram II : A complete record of the emergence and death of tillers of P.T. 50-62 during the period of tillering.

resultant lack of stalk roots, predisposes them to be prey of the sugarcane borers (3).

Stem-formation by tillers.

It was first reported by these authors that the degree of angle of emergence of the tillers determines the extent of their elongative growth and consequently their stem-formation (2, 3). The greater the angle of emergence, the faster is the formation of the stem. Of the four types of tillerings, the stem-formation is fastest in varieties of cup-shaped and fan-shaped tillerings, intermediate in those of bowl-shaped tillering and slowest in dish-shaped tillering varieties. It is probable that the slanting direction of the newly emerging tillers has impeded the normal function of their terminal buds and consequently the mechanism of translocation of their terminal buds and consequently the mechanism of translocation of auxin. It was found that the erectness or the angle of emergence approximately of 80 to 90 degrees of the members of the stool usually promotes the formation of stem. This is especially true of the mother stalk of the stool. As we have reported in the previous papers (2,3), the growth predominance of the mother stalk of the stool in the early period of tillering accentuates as the degree of erectness increases. A good example can be illustrated by the growth predominance of the mother stalk of the fan-shaped tillering.

Table V shows the actual volumes formed in various months of the stool as measured by water displacement method. The stool forms little stem, or internodes, prior to March. It, however, increases greatly at the end of tillering period in May. Almost six months after planting, the stem-formation of the stool begins to accelerate. The causes may be two-fold. First, the low temperature plus dry season, beginning from October to April, retards the elongative growth of the stool. Second, the completion of the "stooling" requires a certain number of stalk roots as well as green leaves, or photosynthetic leaf area, to start with.

TABLE V

THE STEM-VOLUMES (ML.) OF THE STOOL OF P.T. 50-62, FORMED IN VARIOUS MONTHS DURING THE TILLERING PERIOD.

Dissecting	Stem-volumes formed in :								
Months	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Total
Oct.	2.0								2.0
Nov.	2.5	8.6							11.1
Dec.	3.8	24.9	24.9						53.6
Jan.	1.0	24.2	42.2	27.4					94.8
Feb.	1.7	16.0	55.3	111.4	74.0				258.4
Mar.	5.0	19.8	118,0	174.8	331.3	139.1			788.0
Apr.	2.5	40.5	111.8	185.7	277.6	561.0	509.6		1688.7
May	4.0	35.0	145.4	282.5	389.0	1121.1	3229.3	584.0	5790.3

The actual volumes converted into percentages are shown in Table VI.

TABLE VI

PERCENT STEM-VOLUMES FORMED IN VARIOUS MONTHS DURING THE TILLERING PERIOD.

Dissect-ing Months	Per cent. of Stem-volumes formed in : Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May
Oct.	100.0							
Nov.	22.5	77.5						
Dec.	7.1	46.4	46.5					
Jan.	1.1	25.5	44.5	28.9				
Feb.	0.7	6.2	21.4	43.1	28.6			
Mar.	0.6	2.5	15.0	22.2	42.0	17.7		
Apr.	0.2	2.4	6.6	11.0	16.4	33.2	30.2	
May	0.0	0.6	2.5	4.9	6.7	19.4	55.8	10.1

From Table V, it will be seen that the stem volumes formed by the stool prior to March were negligible. They however, rapidly increased from April and greatly increased in May, the beginning of the elongative growth period. Table VI shows that 55% of stem-volumes of the stool was formed in April when dissection was made on May 15. The results obtained show clearly that the stem formation of the stool of September-planted cane was not accelerated until April of the next year under the climatic conditions of Taiwan.

TABLE VII

THE STEM-VOLUMES FORMED BY THE MEMBERS OF THE STOOL MEASURING AT THE END OF THE TILLERING PERIOD (MAY).

Members of the stool	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Total
0*	4.0	24.5	75.0	83.0	52.0	175.0	410.0	60.0	883.5
I	—	2.5	35.3	102.5	116.0	322.5	992.0	171.5	1742.3
II	—	8.0	35.1	97.0	212.8	571.6	1814.8	352.5	3091.8
III	—	—	—	—	8.2	52.0	12.5	—	72.7

*Remarks : O represents mother stalk, while I, II, III represent tillers of primary, secondary and tertiary orders in the stool. Tertiary tillers usually become growth laggards and die.

Furthermore, if the stem volumes formed by the mother stalk and those of tillers of the different orders in the stool given in Table VII were considered, more than 50% of stem volume was formed in April regardless of any member of the stool. It is evident that it is April in which the homogenous growth of the members of the stool has been approached. Since the aim of cane culture in the early part of growth period is to promote the homogenous growth of all members of the stool, it was recommended by the authors (3) that the stem volume formed by the members of the stools can be taken as a reliable indication by which the suitable field operation could be suggested. Any operation such as earthing-up, or filling the planting furrow with the soil before April would impede the homogenous growth of the members of the stool. It is for this reason that the final earthing-up, if there is any, should not be made prior to April in Taiwan for September-planted cane (3).

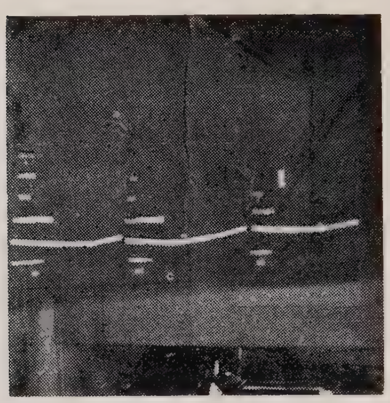


Fig. 8 : The stem formation of the members of the stool in the various months during the tillering period. The stem volumes were mostly from March onward (P.T. 50-62).

The process of stem formation (Table V) of the tillers proceeds slowly prior to March (Fig. 8), only 258.4 ml. being formed by the whole stool. The negligible volume formed within this period by the members of the stool has physiologically delayed the growth dominance of the terminal bud of the respective members of the stool thus enabling free emerging of the tillers. As soon as the volume of the stem formation by each member of the stool has reached 200ml. (3), or 700 to 800 ml. by the whole stool, the terminal bud of the tillers begins its normal dominant function resulting in the inhibition of the emergence of the late tillers. The usual practice of the cane farmers of this island was not to encourage any stem formation in the September-planted cane during the dry, low temperature season by the members, especially by the mother stalk, of the stool so that the stool has plenty of time to develop as many stout tillers as possible.

GREEN LEAF AREA

Throughout the growth cycle of sugarcane plant, the number of green leaves produced by a stool greatly increases during the middle of the tillering period, usually one hundred or more for thick canes and two hundred or more for slender canes, and thrice as many after elongative growth has proceeded. If the green leaf area of a stool is taken into account, it was largest in the elongative period. Green leaf area of a millable stalk irrespective of any member of the stool, is from 5,000 cm^2. to 6,000 cm^2. during this period (5). It takes 8 months of growth for the September-planting canes to form 5,000 cm^2. of green leaf area for each member of the stool (3). It is therefore, not until May, that the members of the stool of September-planted cane possess approximately the same green leaf area for synthetic process, thus enabling them an equal chance in competition for synthetic process. The growth predominance of the mother stalk over other members of the stool begins to decline as they attain about the same green leaf area.

TABLE VIII

INCREASE IN TOTAL GREEN LEAF AREA (CM^2.) OF THE STOOL OF P.T. 50-62, IN VARIOUS MONTHS DURING THE TILLERING PERIOD.

	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May
0	128.7	781.1	2059.1	2073.6	2260.4	3218.2	5766.9	6684.0
I	—	189.1	1802.4	2368.7	4967.4	5895.3	7536.9	13857.4
II	—	—	296.5	764.1	2936.7	7150.0	18302.9	24131.6
III	—	—	—	29.9	6.0	1855.9	—	695.8

Table VIII shows clearly that the green leaf area of the stool increased progressively from February and reached its maximum in May during the tillering period. On referring to the data in Table IV, it will be found that the majority of tillers of the stool emerged just before the great increase in the green leaf area in February. From the sequence of growth of the stool of sugarcane plant, it seems obvious that the emergence of the tillers diminished rapidly as the formation of green leaf area suddenly increased. Again, from Table VII, it is found that the stem-volume formed by the stool increased greatly one month after the increase of green leaf area, *i.e.*, in March. The increase of green leaf area of the stool followed by the increase of stem-volume is especially notable. The accumulation of the stem-volume to 200 ml., or more, by each member of the stool consequently initiates the physiological dominance of the terminal bud over the lateral ones, resulting in the cessation, say crudely, of the tillering phase of growth of the stool. Apparently then, the formation of minimal green leaf area for each member of the stool for elongative growth, say 5,000 ml., is necessary for the establishment of homogenous growth of the stool.

FORMATION OF STALK ROOTS BY THE TILLERS

In the previous papers (2,3) we noticed that the number of stalk roots of the members of the stool varied with the type of tillering as well as with the order of tillering in the same type of tillering, granting that the age of the stool is the same. Among the four types of tillering of sugarcane, the number of stalk roots in a stool is usually greatest in fan-shaped tillering in the middle of tillering period, intermediate in cup-shaped and bowl-shaped tillerings and the least in the dish-shaped tillering. This is especially true before February, *i.e.*, upto five months after planting in September-planted cane. In one of our tests, we found that the average number of stalk roots produced by a stool in February was 244 for fan-shaped, 120 to 180 for cup-shaped and 82 for the dish-shaped tillering varieties. The production of a few stalk roots of the dish-shaped tillering is apparently the main factor contributing to slow elongative growth of this type of tillering. Additional evidence can be seen by the number of stalk roots of the mother stalk obtained from the monthly stool dissection.

TABLE IX

NUMBER OF STALK ROOTS PRODUCED BY THE MOTHER STALK OF THE STOOL IN THE DIFFERENT TYPES OF TILLERING OF SUGARCANE.

Months	Fan-shaped P.T. 43-52	Bowl-shaped P.T. 50-2	Cup-shaped P.T. 50-777	Dish-shaped P.T. 48-67
December	41	25	20	19
January	48	51	35	26
February	84	85	53	37
March	93	108	64	62
April	115	156	119	132
May	147	273	100*	—*

*Infected by sugarcane borer.

Special attention must be paid to the lead in number of stalk roots produced in the early part of tillering by the mother stalk of fan-shaped and bowl-shaped tillering, thus attributing to the fast growth of these two types of tillering.

Though the production of stalk roots by a stool varies greatly with fertility as well as physical properties of soil,the figures might be useful for comparison if they were obtained from the same field in the same crop year.

One very interesting problem is : how long after planting the members of a stool are able to produce approximately the same number of stalk roots so that homogenous growth of the members of the stool could be inaugurated. Results obtained from our recent experiments showed that at least 7 to 8 months (in April-May) after planting the members of the stool of September-planted cane possesed approximately the same number of stalk roots (3). Exception usually occurred in mother stalk of stool which possessed stalk roots far exceeding the other members even in May, eight months after planting.

TABLE X

AVERAGE NUMBER OF STALK ROOTS PRODUCED BY MEMBERS OF STOOL OF P.T. 50-62 IN PARTICULAR MONTHS DURING THE TILLERING PERIOD IN DIFFERENT YEARS.

	0		I		II		III	
Months	1954	1955	1954	1955	1954	1955	1954	1955
Oct.		12						
Nov.		32		4				
Dec.		36		13		3		
Jan.	40	60	5	12		5		1
Feb.	74	93	18	30	7	9		1
Mar.	79	148	33	51	12	15	43	7
Apr.	110	154	78	46	98	23		9
May	135	142	145	99		31		9

Of course, external factors might affect the formation of tillers in a stool and thus the production of stalk roots of the members respectively. The notable case is the infestation of sugarcane borers in the middle of tillering period. Table X shows that in the same variety of P.T. 50-62, the number of stalk roots of the respective member of stool reaches approximately the same in May in 1953-1954 crop year but is greatly different in 1954-1955. The cause of difference in the latter is the heavy infestation of sugarcane borers which destory practically most of the tillers produced in November as well as in December (Diagram II) and delay the emergence of the secondary and tertiary tillers resulting in notable difference in production of stalk roots by the members of a stool. Even the stool is not transformed into the stage elongative growth at normal time. The stool begins homogenous growth among its members as late as in June, one month later than those in a normal year.

Evidence obtained so far shows clearly that a minimum number of stalk roots, say 50, for each member of the stool is necessary for the formation of stem.

CONCLUSION AND DISCUSSION

Tillering is a phase of development of sugarcane plant while the type of tillering is a trait inherited from the parents. Four types of tillering are found in sugarcane if the "stooling" habit is closely examined during the period of tillering. The main factor determining the type of tillering is the angle of emergence formed with the ground surface by the tillers. The variations in this angle of the members of a stool are characteristic of various types of tillerings.

Of the four types of tillering, the dish-shaped tillering occupies the largest space, while the bowl-shaped and cup-shaped tillerings are intermediate, fan-shaped tillering occupying the smallest space, if the space of the single stool is compared. Any modification by physical means of the angle of emergence of the members of the stool would consequently modify the type of tillering. It is no wonder that the heavy covering of the planting furrow, with soil or hilling in the early part of tillering period would perfectly change the type of tillering. It is also true of dense planting.

The mortality of the tillers is mainly determined by the time of emergence and the elongative growth of the tillers themselves. The latter again is determined by the angle of emergence of the tillers. The elongative growth of the tillers which have a large angle, 70 to 90 degrees, *i.e.*, those which are more or less erect is usually fast and vigorous while it is slow and poor in tillers which, with a small angle, approximating 10 to 20 degrees stand slantingly or sprawl on the ground surface. Dish-shaped tillering is a good example of stooling with sprawling mother stalk and tillers.

As regards the development of tillers in the September-planted cane, the formation of tillers always proceeds the formation of green leaves which in turn precedes the stem formation and production of stalk roots. In order to produce satisfactorily stools early in the tillering period, it is obvious that proper attention to the cultivation practices, such as time of cultivation, time of application of fertilizer, time of irrigation and time of filling the planting furrow with soil, would be a great deal beneficial in completing the stooling of the plant cane. Thus the early accomplishment of homogenous growth of the members of the stool is obtained.

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In the absence of the author the following paper was taken as read.

Paper

A CRITICAL AND COMPARATIVE STUDY OF H.M. 320 AND Co. 419 VARIETIES OF CANE

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In the Mysore State, sugarcane is being grown in the Visweswaraya Canal tract from 1933 onwards, when the whole area was brought under channel irrigation. All these years, most of the cane that is grown by the ryots, in this area is under contract to the Mysore Sugar Co., Ltd., (Factory situated at Mandya) for the manufacture of white sugar. H.M. 320 (Hebbal Mauritius) variety of cane, which was developed by the Department of Agriculture, Mysore, was the only variety grown till the year 1942. It was observed that there was a steady decline in this variety of cane, both in quality and the yield, particularly from the year 1939 onwards. After various trials on the Company Farms, Co. 419 variety of cane developed by the Sugarcane Research Institute at Coimbatore, South India, was introduced from the year 1942. By the year 1945 practically the entire area of about 13 to 14 thousand acres was under this variety. Thus it can be said that for the last 22 years, there are only two varieties, which have been predominantly grown in this area. A comparative and critical study of both the varieties from all aspects , both in the field and the factory was made.

One of the advantages in this area is that water is available for irrigation throughout the year, except for the time when it is closed for small duration for channel cleaning. Under normal conditions, up to the year 1944, cane planting was done from February to December. But after the year 1945, planting is being done mostly from June to December and that too, the major portion of the area is planted in the months of June, July and August.

The earlier plantings of February to May were classed as summer plantings or first season plantings and June to December plantings as second season plantings or rainy season (Adsali) crop. There was no planting in the latter half of December and the month of January due to channel cleaning and also due to the fact that this is the harvesting period for paddy. The system of rotation in this area is sugarcane—green manure crop—paddy. The soil in this area varies from sandy loam to clayey soils fed by channel irrigation and tank irrigation respectively.

In order to give an idea of the climatic conditions in this area, the average temperatures and the rainfall distribution is given in Table I :—

TABLE I

Months.	Temperature Max. °F.	Temperature Min. °F.	Rainfall inches.
January	84·6	60·5	Nil
February	89·7	61·3	Nil
March	96·6	65·0	0.90
April	96.3	68.8	2.95
May	97.3	71.8	3.10
June	98.8	68.7	5.90
July	88·0	69·3	0·10
August	81.9	64.7	1.25
September	82.9	65.1	6.85
October	88.6	68.3	7.95
November	86.4	61.3	2.70
December	85.8	59.1	Nil

A comparative statement showing the field observations made for both the varieties of H.M. 320 and Co. 419 is given below :—

H.M. 320	Co. 419
1. Grows best on good and medium type of soils and particularly well on alluvial soils.	1. Grows best on all types of soils, including slightly alkaline soils.
2. Germination is slow and only about 10% by about the 4th week. Complete germination takes about 45 days and germination percentage is 90.	2. Germination is about 15 to 18% by about the 4th week and complete in 40 days. Germination percentage is 95.
3. Growth is slow during the first five months after planting but improves after final earthing up.	3. Growth is very rapid throughout and responds well to heavy manuring.
4. Gives only 3 to 4 tillers per stool. There is a tendency to develop grassy growth.	4. Gives 6 to 7 tillers per stool.
5. Thrives well both as a summer crop and rainy season crop (also called first and second season crops respectively).	5. Thrives well only as rainy season crop and that too best planting months are June, July and August.
6. Flowering is practically nil. In rare cases when grown on alluvial soils, there is sporadic flowering on a small scale.	6. Flowering is universal and occurs in the month of October. Even crops 7 to 8 months old flower.

7. Lodges heavily and thus difficult to harvest. Besides, leaf blades stick to the cane.	7. Does not lodge much and easy to harvest. The leaves are held loose.
8. Yield 30 to 35 tons on heavy soils.	8. Yields 40 to 45 tons on heavy soils.
9. Does not ratoon well on medium and light soils.	9. The first ratoon is good on all types of soils.

The peculiar phenomenon observed in the two varieties are as follows :-

H. M. 320 : It was observed that February, March and April plantings were very much susceptible to stem borer attack. The borer attack is more a seasonal one, *i.e.*, attack occurring in the month of May when the crop is 6 to 8 weeks old. In some instances 80 to 90% of the crop is wiped out. But the second season plantings from June onwards are not affected.

Co. 419 : The first season plantings flower in the month of October, when the crop is about 7 to 9 months old. The second season plantings also flower in October when they are 10 to 14 months old.

Yield : The yield of H.M. 320 and Co. 419 planted on the same date and grown under similar conditions and harvested at the same age was 47.5 tons and 66.3 tons per acre respectively. The maximum yield of Co. 419 cane registered on the Mysore Sugar Co., farms is 104 tons per acre. The ryots have grown up to 70 tons per acre over 5 acres plots for Co. 419 while it was 50 to 55 tons from H. M. 320.

ANALYSIS

Canes of both the varieties planted in different months of the year were analysed every month from the 12th month onwards. For purposes of comparison they are divided into 3 groups as (i) February to May plantings (Summer crops) (ii) June to July and August plantings (rainy season crops) (iii) September to December plantings (winter crops). A summary of the analysis figures and observations thereon are given below.

SUMMER PLANTINGS

H.M. 320 planted from Feb. to May attains maturity in 12 to 13 months time. The purity is 91-92 but the reducing sugar content is high being 1 to 1.2%. The peak purity of 94-95 and R.S. 0.18 to 0.23 is reached in the month of August, when the crops are 17 to 18 months old. They retain these high purities even when the crop is 20-21 months old.

The R. S. content at this time ranges from 0.36 to 0.44.

Co. 419 planted in the summer months, at the same age of 12 to 13 months had definitely lower purity. The purity is above 90 when the crop is 11 months old, but there is a sharp fall in purity from the 13th month onwards. At the

14th month it reached the lowest level of 81-82. As stated earlier in the summer plantings flowering commences in the month of October. This is one of the reasons for the sharp fall in purity after the 13th month. It was also observed that the brix of the juice of Co. 419 of summer plantings was very low. It was 17 to 18° at the 12-13 months age as against 21 to 21.5° of H.M. 320 of the same age. This indicates the poor formation of sugars in Co. 419.

From the above results it can be definitely said February, March and April plantings of H.M. 320 are better in keeping quality than Co. 419 planted in the same months.

RAINY SEASON PLANTINGS

June, July and August plantings of Co. 419 mature in 13-14 months time, the purity and R.S. being 91-92 and 0.30 to 0.46 respectively. They attain the peak purity of 94-95 and R.S. of 0.25 to 0.32 in the month of October, just before the commencement of flowering. From the 17th to 18th month onwards there is a drop in purity and a consequent rise in the R.S. content. After 20 months the purity and R.S. range from 86 to 88 and 0.67 to 0.88 respectively.

H. M. 320 plantings of the same month has 86-88 purity and 0.83 to 1.05 R.S. content at the 14-15th month as against 94 to 94.5 purity and 0.5% R.S. content for Co. 419 of the same age. Maximum purities for the June, July and August plantings of H.M. 320 are attained only after 17-18 months duration, it being 94-95 purity and 0.20 R.S. as against 15-16 months for Co. 419. But for the same age of 21 months H. M. 320 has 91.8 purity and 0.52 R. S. as against 89.6 purity and 0.67 R. S. for Co. 419. The late maturing quality of H.M. 320 may be one of the reasons for its better keeping quality.

WINTER CROPS

The September, October and November plantings of Co. 419 ripen at the 14th month, the purity and R.S. being 91-92 and 0.46 respectively. The maximum purity of 93-94 is reached at the 15th month. But when compared with June and July plantings, for the same age, the winter plantings show less purity and a higher R.S. content for the same duration of 18 months. The June, July and August plantings had 90-92 purity and 0.35 to 0.57% R.S. as against 84-88 purity and 0.9—1.1% R.S. for September, October and November plantings.

In H. M. 320 of September and October plantings, the purity figures are about the same as June, July and August plantings. But there is a marked difference in November plantings. The maximum purity is only 92.3 and 0.51 R.S. at the 17th month as against 93.5 to 94 purity and R.S. of 0.28% for September and October plantings of the same age. But unlike Co. 419 the fall in purity in succeeding months is not so steep. Also for the same age of 17-18 months, H.M. 320 has a better purity (92 to 94 purity and 0.28 to 0.35 R.S.) as against 88 to 89 purity and 0.73 to 1.0 R.S. for Co. 419. This is a decided advantage to the factory as these crops are to be milled at a time when atmospheric temperatures are at their peak.

Thus it can be said that June, July and August plantings, of Co. 419 are at their best when 15-16 months old. For the same duration September to November plantings show less purity.

In case of June to October plantings of H.M.320, the peak purity is obtained when they are 17-18 months old. H.M. 320 has a better keeping quality even when the crops are 20-21 months old.

MILLING TEST

A detailed milling test carried out in a 34″ × 78″ fifteen roller tandem showed the following results :

TABLE II

	Co. 419		H.M. 320	
Weight of cane	37 tons		33.3 Tons	
Juice % cane	72 %		100 %	
Maceration	13.8%		18%	
Mill Juice analysis :	Brix	Purity	Brix	Purity
Crusher juice	19·4	90.5	19.2	90.7
Mixed juice	15.5	88.0	15.8	87.8
Last Mill juice	9.4	84.36	7.7	80.39
Settling time	1 hour 25 Min.		1 hour 30 Min.	
% of scum	30 to 32 %		35 to 38 %	
Clarity of juice				
Top	38 (Kopke)		28 (Kopke)	
Middle	40		30	
Bottom	21		26	
Average	33		28	
Juice % cane in hand mill	54·1		51.2	
Pol % cane	14.83		15.65	
Fibre % cane	13.0		12.0	

Juice % cane is not so indicative as the quantity of cane crushed is very small.

From the above results it can be seen that the juice of Co. 419 have better settling qualities and the clarity of the juice is better for Co. 419 than H.M. 320 by 5 units. As against this, the sugar in cane in H.M. 320 is more than in Co. 419. But the juice % cane of Co. 419 is more than H.M. 320. This, to a certain extent, off-sets the lesser sugar content in Co. 419. It may also be seen that the fibre % cane in Co. 419 is more than H.M. 320. The fibre content of Co. 419 is very much increased from month of January onwards due to the fact that pith formation is maximum at this time when flowers just drop off. The maximum fibre content in Co. 419 reaches 14-15% as against 12-13% for H.M. 320.

YIELD OF SUGAR PER ACRE

It may be seen from the figures above that the Pol % of H.M. 320 is higher by 0.82%. But as stated earlier, Co. 419 is a heavy yielder. H.M. 320 and Co. 419 planted, grown and harvested under similar conditions yielded 47.5 tons and 66.3 tons respectively.

Taking 75% over-all recovery on the pol % cane, *the yield of sugar* per acre will be as follows :

H.M. 320 ..	12,432 lbs. (or 5.55 long tons)
Co. 419 ..	16,508 lbs. (7.37 long tons)

Hence, it can be said conclusively that even though the Pol % cane in H.M.-320 is more than Co. 419, the higher yield of Co. 419 will ultimately give more sugar per acre by nearly 30%.

MANUFACTURING QUALITIES

H.M. 320. The quality of fibre of H.M. 320 is not so hard and does not give much trouble in milling operations. The average fibre content is 11 to 12%. The lowest being 9.5% and the highest being 13.0%. With about 18% to 19% maceration, an average extraction of 92% is obtained in a tandem of 3 roller crusher and four mills.

The juice of H.M. 320 is difficult to clarify. Especially with over ripe cane, the scums are very thin and slimy and not easily filterable. When H.M. 320 of 16 to 18 months is milled the manufacturing qualities are at the best. But when over-ripe cane of (22 to 23) months is being milled, despite the fact that purities are high, the clarification is difficult. The juice from over-ripe cane is wanting in phosphate content. More lime is required for better settling. Another trouble encountered was that the colour of the clarified juice was dark brownish. In order to bleach it, heavy sulphuring of syrup, sometimes up to 4.6 pH had to be resorted to.

Co. 419. The average fibre content ranges from 12 to 14% and in summer months goes up to 15%. The increased maceration does not improve extraction very much. The juice of Co. 419 contains more wax. Heavy liming is necessary, sometimes up to 0.27% cane as against 0.12 to 0.15% cane when H.M.-320 was being milled. But the quality of scum is definitely better and easily filterable. The quantity of scum is also less. Due to the easy filterability of scums, the consumption of filter cloth is lessened. The average clarity of the juice was more and there is no necessity to sulphite the syrup heavily and 5.2 to 5.4 pH is quite enough.

INFLUENCE OF AGE FACTOR ON THE QUALITY OF CANE

Under normal conditions in this area, the duration of the crushing season is about 8 to 9 months in the year. Thus we are forced to mill cane ranging from 13 to 20 months duration. On account of this, there is a wide range in the quality of the cane. As stated earlier, Co. 419 yields best when planted in June, July and August months. Hence after the introduction of this variety a large portion of the total area planted is concentrated in these months.

During the transition stage when H.M. 320 was being gradually replaced by Co. 419, a correct account of the quanitity of cane supplied from the different planting months of the year and milled in different months of the crushing season was maintained. These figures can be correlated with the quality of cane when (1) H.M. 320 and Co. 419 were being milled in different proportions and (2) when only Co. 419 was being milled. (Tables III, IV and V)

From the above figures we can observe as follows :—

1. From September to January, when Co. 419 and H.M. 320 were being supplied in nearly equal proportions, and out of this supply, the June, July and August plantings formed the bulk, the sugar % cane was steady and there was not any appreciable rise in the reducing sugar content. This is due to the fact that the June, July and August plantings of Co. 419 are at their best when 14 to 15 months and retain the high purity till about December. But it may be seen that the fibre content was increased from November to January. This is due to the fact that arrowing will have commenced by then, which increases the pith formation and consequently the fibre content from 12% in October to 13.6% in January.

For the month of February and March, when out of the total supply nearly 75% to 80% consisted of H.M. 320 variety and even in this 65% consisted of September to December plantings, there is only slight fall in Pol % cane and the fibre content is lessened. This is due to the fact that September to December plantings of H.M. 320 attain maximum purity only after 17 to 18 months duration.

But in April and May, when H.M. 320 formed the bulk and out of this nearly one third of the total supplies consisted of February-April plantings, 12-13 months old, there is a sharp fall in the Pol % cane. It is 12.39% in April and 11.23% in May as against 14% in the month of October. Also the R.S. content is nearly doubled from 0.7% to 1.34%. This is due to the fact that the summer plantings of H.M. 320 even though they have high purity when 12 to 13 months, the R.S. content is initially high.

From the figures for the year 1945-46 and 1946-47, it will be seen that in almost all the months of crushing season, more than 90% of the supplies consisted of Co. 419 variety of cane. It will be seen that in both the years, the sugar content of cane is nearly steady till January, when 60 to 70% of supplies consisted of June and July plantings. It is only in the month of March that there is a sharp fall when 60% of the supplies consisted of September to December plantings. In the year 1946-47 during the months of February, March and April, there is a big rise in the fibre content due to the fact that more than 75% of the supply consisted of September to December plantings. The reducing sugar content was 0.7% in November when 60% of the supplies consisted of June-July plantings

TABLE III.

PERCENTAGE OF SUPPLIES FROM PLANTINGS OF DIFFERENT MONTHS DURING 1943—1944 SEASON.

Month of crushing	% of monthwise plantings of 1942 and 1943				Proportions		Pol % cane	Reducing Sugar %	Fibre %	Remarks
	Feb. to Apr. 42	June to Aug. 42	Sept. to Dec. 42	Feb. to Apr. 43	H.M. 320	Co. 419				
September, 1943.	28	69	3	—	58.8	41.2	14.61	0.80	11.99	62% of June & July only.
October, ,,	23	70	7	—	53.7	46.3	14.31	0.71	12.05	61% —do—
November ,,	15	76	9	—	47.7	52.3	14.09	0.74	13.51	66% —do—
December ,,	8	71	21	—	48.8	51.2	15.05	0.83	13.37	59% —do—
January, 1944	—	67	33	—	55.5	44.5	13.83	0.89	13.60	52% —do—
February ,,	—	41	56	3	74.3	25.7	13.87	0.85	12.24	44% of Sept. & October.
March ,,	—	27	65	8	83.1	16.9	13.40	1.1	13.10	50% —do—
April ,,	—	15	54	31	82.1	17.4	12.39	1.34	12.15	30% of Feb. & May.
May ,,	—	17	48	35	80.5	19.5	11.23	1.76	14.28	34% —do—

TABLE IV

PERCENTAGE OF SUPPLIES FROM PLANTINGS OF DIFFERENT MONTHS DURING 1945-1946 SEASON.

Month of crushing	% of monthwise plantings of 1944 and 1945				Proportions		Pol % cane.	Reducing Sugar %	Fibre %	Remarks.
	Feb. to Apr. 44	June to Aug. 44	Sept. to Dec. 44	Feb. to Apr. 45	H.M. 320	Co. 419				
September, 1945	16	75	9	—	7.2	92.8	14.23	0.95	11.95	55% of June & July.
October ,,	9	76	15	—	6.8	93.2	14.25	0.99	12.93	—do—
November ,,	5	75	20	—	5.3	74.7	13.80	0.83	12.79	—do—
December ,,	5	68	27	—	3.9	96.1	14.16	0.85	12.53	52% —do—
January 1946	—	62	33	5	2.0	98.0	14.25	0.91	12.94	50% —do—
February ,,	—	54	41	5	1.6	98.4	13.98	1.32	12.73	35% of Sept. & Oct.
March ,,	—	35	60	5	1.4	98.6	13.28	1.60	12.58	50% —do—

TABLE V

PERCENTAGE OF SUPPLIES FROM PLANTINGS OF DIFFERENT MONTHS DURING 1946-1947 SEASON.

Month of crushing	% of monthwise plantings of 1945 and 1946.				Proportions		Pol % cane.	Reducing Sugar %	Fibre %	Remarks
	Feb. to Apr. 45	June to Aug. 45.	Sept. to Dec. 45	Feb. to Apr. 46	H.M. 320	Co. 419				
September 1946	18	73	9	—	11.1	88.9	13.97	0.93	11.68	58% of June & July.
October ,,	9	78	13	—	2.1	97.9	14.13	1.10	10.88	60% —do—
November ,,	4	80	16	—	1.1	98.9	13.77	0.73	12.31	50% —do—
December ,,	—	71	29	—	0.8	99.2	13.57	0.68	12.35	43% —do—
January 1947	—	56	44	—	0.7	99.3	13.59	0.88	12.34	38% of Sept. & October.
February ,,	—	24	76	—	—	100.0	13.34	1.17	12.69	56% —do—
March ,,	—	11	89	—	—	100.0	12.55	1.54	13.20	63% —do—
April ,,	—	9	91	—	—	100.0	12.09	1.60	13.60	67% —do—

as against 1.6% in the month of April when 91% consisted of September to December plantings.

It is interesting to compare the above with the figures for previous years when only H.M. 320 cane was milled. During the year 1939-40 when H.M. 320 was milled in its optimum condition, the Pol in cane during the crushing months of September to March ranged from 13.6 to 13.7% with a reducing sugar content of 0.7 to 0.8%. But when the February to May plantings were commenced from the first week of April, there was a sharp fall in the Pol % cane. It was 12.2 and 10.7 in April and May respectively, while the reducing sugar increased to 1.3 to 1.4 per cent.

During the year 1941-42 when over-ripe H.M. 320 cane of 22 to 24 months was being milled the Pol in cane was ranging from 11.2 to 12.5%. The maximum sugar content was only 12.65%.

Thus it can be said conclusively that from the factory's point of view, June, July and August plantings of Co. 419 are more advantageous than September to December plantings. For the H.M. 320 variety, June, July and August plantings are at their best, if harvested only after 16-17 months. But milling only February to May plantings of H.M. 320, when they are 12-13 months old is not advantageous. It is true that normally, the Pol in cane and the recovery in summer months is low. But the initially high R.S. content in the first season plantings of H.M. 320 does affect the recovery still more.

FLOWERING IN Co. 419*

Flowering or arrowing as it is often called is universal for Co. 419, in this part of the country. It happens in the month of October. The summer plantings flower when they are 6-8 months old. Arrowed canes are lighter in weight and pith formation is very prominent. The purity of arrowed canes is high, but the glucose content is also high.

June to August plantings are not much affected by arrowing but for the September to November plantings, there is a sharp fall in purity and a rise in R.S. content after flowering commences.

Hence, for Co. 419 even though flowering hastens the ripening in summer plantings, it does not help the factory operations as the initial R.S. content itself is high.

H.M. 320 is a non-flowering variety. Sporadic cases of flowering were only noticed in September and October plantings. The arrowed canes had 93-94 purity and 0.29 to 0.34% R.S. as against 90 purity and 0.42% R.S. for non-arrowed canes. The percentage of arrowing was only 15. Flowers appeared in the middle of November.

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*For more detailed information refer. Kalbagal, Indian Sugar Volume10 ; 6-7 pp., 110-112.

DRIAGE AND DETERIORATION*

During the winter months of October to December for the same duration of 96 hours the driage losses for Co. 419 and H.M. 320 are about the same. But in summer months of March and April the driage loss for Co. 419 is more than H.M. 320 by nearly 50% for the same duration of 96 hours.

With regard to deterioration losses, in the winter months the rate of deterioration for Co. 419 is less than in H.M. 320. But in summer months it is just the reverse. One of the reasons for this may be the fact that H.M. 320 will have attained peak purity just at the commencement of the summer and thus the losses are very much minimised.

SUMMARY

H.M. 320 may be said to be an all season cane. The February to April plantings mature within 12 months but the reducing sugar content is rather high. The first season (summer) plantings keep up the purities till 18th months and in some cases even upto 20 to 21 months. It was observed that the first season plantings were very susceptible to stem borer attack. The second season plantings (June to December) mature only after 15-16 months. They retain good purities till 20 months. Best results are obtained when H.M. 320 of 17-18 months age is milled.

Co. 419 is essentially a second season cane. More so, it thrives best when planted in the months of June, July and August. From all points June, July and August are the best months for planting. For the same age, June, July and August plantings show better purity than September, October and November plantings. For the same age of 20-21 months H.M. 320 has a better purity than Co. 419. But, for the 14-15 months crop, Co. 419 has a better purity than H.M. 320.

The effect of early and late maturing qualities on the sugar content in cane, could be very well seen, when these varieties were being milled. When H.M. 320 of February to April plantings, only 12-13 months old, was milled in large quantities there was a fall in the Pol in cane and a rise in reducing sugars. When September to December plantings of Co. 419 formed the major part of the total supplies, there was a marked decrease in the Pol in cane.

Co. 419 is definitely a better yielder than H.M. 320. The Pol in cane for Co. 419 is a little less than H.M. 320. But the higher juice % cane of Co. 419 to a certain extent offsets the low Pol in cane. The fibre content of H.M. 320 is less than Co. 419.

Even though the sugar content is more in H.M. 320 than in Co. 419, the higher yield of Co. 419 gives more sugar per acre.

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*For more detailed information, please refer,

(1) Kalbagal, Indian Sugar. Volume 1, July 1951 pp., 25-31.

(2) Subbiah, Journal of Mysore Agricultural and Experimental Union, 17-4 pp., 173.

The juice of H. M. 320 is rather difficult for clarification due to its refractory nature. It is more so when the juice from over-ripe cane is being milled. Even though the purity of the 21-22 months H.M. 320 cane is high, the clarification of these juices present a problem. The quantity of the scum is more and not easily filterable. Heavy sulphuring is to be done to remove the colouring matter.

The juice of Co. 419 responds to clarification treatment well and the clarity of the juice is definitely better. But the wax content is more than that of H.M. 320. Heavy liming is necessary.

H.M. 320 is a non-flowering variety while Co. 419 flowers invariably in the month of October. Flowering in Co. 419 accelerates the ripening in the first season plantings, but the reducing sugar content is very high. June, July and August plantings are not much affected but arrowing has a retarding effect on the purity and reducing sugars in September, October and November plantings. For all plantings, pith formation is prominent after flowering.

During the winter months, the driage and deterioration losses for cut cane are less in Co. 419 than in H.M. 320. But in the summer months of March and April, the driage and deterioration losses for Co. 419 are much more than H.M. 320.

I thank the Management of the Mysore Sugar Company Limited for affording me all facilities to study this problem.

MANURIAL

Dr. H. Evans presented the following paper

Paper

SOME PRELIMINARY RESULTS FROM FERTILIZER TRIALS INVOLVING VARIOUS COMBINATIONS OF MAJOR AND MICRONUTRIENTS ON BRITISH GUIANA PORTLAND CLAY SOILS.

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INTRODUCTION

The results of representative trials from a series of 3N × 3P × 3K factorial trials with split plots testing limestone versus no limestone were recently described (Evans et al 1954).

In one or two of these trials a depressing effect on cane tonnage of potassium in the absence of nitrogen was shown to be due to the suppression of magnesium uptake. Although generally magnesium is adequate or high in British Guiana frontland clays, occasions have occurred where the application of 6-8 cwts. of muriate of potash in the absence of adequate nitrogen has resulted in the suppresion of magnesium uptake to an extent sufficient to produce visual symptoms of magnesium starvation (Evans 1955). Sulphate of ammonia greatly increases magnesium uptake and this was responsible for a marked interaction between nitrogen and potash so that significant positive responses occurred to potash at high nitrogen levels whilst there was a depressing effect of potash on tonnage at low nitrogen levels. As only sulphate of ammonia has been used as a nitrogenous fetilizer it should be understood that the word "nitrogen" as used above refers to this material and there is no evidence to date as to whether it is the ammonium ion or the sulphate ion that is responsible for the effect on magnesium uptake.

In order to investigate these effects further, some two dozen 3P × 3K × 3Mg trials were laid down and split plots were used to investigate the effect of micronutrients. In this series of trials the micronutrients used were as follows :—

Copper sulphate 50 lbs./acre.
Zinc sulphate 25 lbs./acre.
Sodium borate 20 lbs./acre.
Sodium molybdate 1 lb./acre.

No iron or manganese was used since previous work had shown that these two elements were already adequate or were excessive in the frontland clays. Each trial was to receive a basic dressing of ½ ton limestone/acre before planting ; but in some of the trials a basal dressing of 6 tons limestone/acre was applied. All the trials received 4 cwts. sulphate of ammonia per acre and the three major variables were as follows:—

Muriate of potash at 0, 1½ cwts. and 3 cwts./acre.
Triple super phosphate at 0, 2 cwts. and 4 cwts./acre.
Epsom salts at 0, 3 cwts. and 6 cwts./acre.

Four of these trials are described in some detail.

A second series of trials consisted of a combination of the main factors,

(*i*) Sulphate of ammonia alone at 4 cwts./acre.
(*ii*) a basic dressing of 5 tons/acre of limestone together with 4 cwts. sulphate of ammonia.
(*iii*) an application of 6 cwts. super phsophate and 1 cwt. muriate of potash together with 4 cwts.sulphate of ammonia.

With the following treatments as the second variable.

(*a*) no futher treatment.
(*b*) the application of 150 lbs./acre of DuPont Co.'s "fritted trace elements".
(*c*) a compounded micronutrient treatment consisting of 25 lbs. zinc sulphate, 25 lbs. sodium borate and 3 lbs. ammonium molybdate per acre applied at planting supplemented by a foliage spray of 50 ppm copper, 25 ppm zinc, 25 ppm boron and 1 ppm molybdenum at the age of 5 months.

Five of these trials are described in some detail.

Finally a third series of trials followed from the identification of molybdenum deficiency symptoms in a field of the variety B. 4098 growing in a badly compacted silty clay at Uitvlugt estate. These trials consisted of 8 × 8 latin squares with the following treatments :

(*i*) Control plots given normal nitrogenous deressing as S/A.
(*ii*) Normal S/A +3 tons limestone below in row+2 tons limestone on top (in row).
(*iii*) Normal S/A +5 tons limestone broadcast and incorporated.
(*iv*) S/A and limestone as (*iii*) +4 cwts. super phsosphate +3 cwts. muriate of potash.
(*v*) Normal S/A +4 cwts. super phosphate +3 cwts. muriate.
(*vi*) Normal S/A +1 lb./acre ammonium molybdate.
(*vii*) Normal S/A +1 lb. molybdate +4 cwts. superphosphate + 3 cwts. muriate.
(*viii*) As (*vii*) but with addition of 5 tons limestone.

The general conclusions from these trials are presented.

FIRST SERIES OF TRIALS—3K × 3P × 3Mg TRIALS WITH AND WITHOUT MICRONUTRIENTS.

TRIAL No. 1. SKELDON ESTATE SECTION 82 FLD. 19. VARIETY B.41227

The data collected during the growth of the cane are presented in Table I. The Vegetative growth index refers to the weight of a standard number of the leaves showing top visible dewlap—generally 30 such leaves.

TABLE I

SUMMARY OF THE MAIN EFFECT VEGETATIVE GROWTH INDICES AND CORRESPONDING ANALYSIS AT THE THREE SAMPLING PERIODS.

Factor	Micro nutrients	Age (Weeks)	V.G.I. at levels			Mineral analysis of % dry matter at levels		
			0	1	2	0	1	2
K	—	16	430	486	580	1·24	1·43	1·52
	+		464	463	371	1·26	1·43	1·48
K	—	20	545	586	613	1·23	1·30	1·30
	+		513	574	568	1·19	1·33	1·28
K	—	24	616	642	626	1·18	1·17	1·18
	+		600	625	645	1·21	1·23	1·18
P	—	16	454	543	498	0·182	0·223	0·237
	+		324	454	520	0·170	0.204	0.240
P	—	20	545	602	596	0·180	0·184	0·200
	+		490	585	581	0·164	0·182	0·196
P	—	24	630	655	599	0·176	0·161	0·166
	+		620	638	613	0·165	0·163	0·179
Mg	—	16	505	484	506	—	—	—
	+		412	458	427	—	—	—
Mg	—	20	591	569	583	0·301	0·309	0·329
	+		548	557	550	0·284	0·299	0·313
Mg	—	24	639	630	615	—	—	—
	+		603	635	633	—	—	—

The mean contents of other elements at the three sampling periods for the ± micronutrient plots were as follows :

		Sampling age in weeks.		
		16	20	24
Nitrogen	—	2·44	2·34	2·02
	+	2·35	2·33	2·02
Calcium	—	—	0·234	—
	+	—	0·246	—
Manganese (PPM)	—	—	219	
	+	—	185	—
Iron (PPM)	—	—	78	—
	+	—	77	—

+ means with micronutrients ; — means without micronutrients.

HARVESTING DATA

The harvest data are shown in Table II.

TABLE II

	Micro nutrients	K_0	K_1	K_2	P_0	P_1	P_2	Mg_0	Mg_1	Mg_2
Tons cane	+	56·1	62·1	62·9	50·3	64·5	66·4	59·3	61·4	60·5
per acre	—	58·8	65·1	66·6	57·2	65·4	67·8	66·4	61·8	62·3
Sucrose %	+	12·24	12·10	12·24	12·36	12·09	12·13	12·47	12·52	11·59
cane	—	13·06	12·43	11·84	12·52	12·25	12·56	12·53	12·43	12·38
Purity	+	82·95	83·08	81·81	84·29	81·55	82·00	83·73	82·79	81·32
	—	84·29	82·35	81·61	83·21	81·95	83·09	83·30	82·70	82·25
Phosphate	+	30	29	31	23	31	38	31	29	31
PPM in juice	—	36	30	43	35	34	40	32	36	42

TWO-WAY TABLES OF TONS CANE PER ACRE

		P_0	P_1	P_2	Mean
K_0	+	39·7	62·2	66·4	56·1
	—	50·1	60·6	65·7	58·8
K_1	+	54·3	66·0	66·1	62·1
	—	56·9	68·8	69·5	65·1
K_2	+	56·9	65·1	66·7	62·9
	—	64·6	66·9	68·2	66·6
Mean	+	50·3	64·5	66·4	60·0
	—	57·2	65·4	67·8	63·5

		Mg_0	Mg_1	Mg_2	Mean
K_0	+	54·1	56·4	57·8	56·1
	—	60·1	60·5	55·9	58·8
K_1	+	61·3	65·5	59·6	62·1
	—	70·0	64·3	60·9	65·2
K_2	+	62·4	62·2	64·1	62·9
	—	69·1	60·5	70·1	66·6
Mean	+	59·3	61·4	60·5	60·0
	—	66·4	61·8	62·3	63·5

		P_0	P_1	P_2	Mean
Mg_0	+	49·7	62·2	75·9	62·6
	—	56·9	72·0	70·3	66·4
Mg_1	+	49·1	66·8	68·2	61·4
	—	55·8	62·0	67·4	61·8
Mg_2	+	52·1	64·4	65·1	60·5
	—	58·9	62·3	65·7	62·3
Mean	+	50·3	64·5	66·4	60·0
	—	57·2	65·4	67·8	63·4

DISCUSSION OF RESULTS

The analytical results showed that the cane in the trial was adequately supplied with nitrogen throughout the growth period. Potash was also adequate although some values near the critical level of 1.20% K occured in the six month samples.

Phosphorus was inadequate in the absence of phosphate fertilization but was brought up to the adequacy level by the first and second levels of phosphate fertilization at 4 months and by the second level of phosphate fertilization at 5 months.

The calcium status of the cane was highly favourable being well above the critical value for calcium and the status as regards magnesium, manganese and iron was normal.

There is evidence from the vegetative growth index that the micronutrients exerted an initial toxic effect which was particularly marked at the second level of potash and at the zero level of phosphate. It is possible that the phosphate effect would be brought about by the insolublization of copper and zinc as phosphates, whereas muriate of potash would be expected to hold them in solution and possibly thus enhance uptake. At the age of 5 months the apparent depressing effect of the micronutrients was less than at 4 months and by 6 months had almost disappeared.

The behaviour of the vegetative growth index is in harmony with the final yields of cane per acre.

The over-all effect of micronutrients in this trial was a reduction of 3½ tons cane per acre. Further analysis shows that the major portion of this yield reduction occurred in the no-phosphate treatment combinations—where the over-all yield reduction was 6.9 tons cane per acre. This micronutrient effect is significant in the analysis of variance table. At the P_1 and P_2 levels there were no significant micronutrient effects.

The large response to phosphate consisting of an increase in yield of 10.6 tons of cane in the absence of micronutrients and 16.1 tons cane in their presence is highly significant.

There is also an unexpected positive response to potash of 7 to 8 tons of cane. There was a striking increase in the phosphorus content of the leaves at 4 months as a result of potash fertilization. Potash brought the phosphorus content up from the definitely deficient level of 0.17% P to the adequacy levels of 0.204% and 0.240% in the plus micronutrient plots and from the deficiency level of 0.182% to the adequacy levels of 0.223% and 0.237% in the minus micronutrient plots. It is therefore, concluded that the response to potash is an indirect one brought about by the effect of potash on phosphate uptake under these particular conditions. The major portion of the potash effect occurs, as would be expected if this explanation is correct, in the plots not receiving phosphate fertilizer.

Application of magnesium as epsom salts had a slight depressing effect on cane yields and even more definitely on quality. This would be expected from the foliar magnesium content which was somewhat high. Under these conditions potash resulted in a deterioration in juice quality contrary to its effects when a deficiency of the element is rectified. Phosphate had no consistent effects on quality, but the phosphorus content of the juice was definitely increased by phosphate fertilization.

TRIAL NO. 2. PORT MOURANT ESTATE FLD. ANKERVILLE E.E. 38 B. 41227.

Treatments were identical to those given in Trial No. 1.

The main effect vegetative growth indices and corresponding analyses at the three sampling periods are summarized in Table III.

TABLE III

Factor	Micro-nutrients	Age (Weeks)	V.G.I. at levels			Mineral analysis of % dry matter at levels		
			0	1	2	0	1	2
K	—	16	427	425	455	1.15	1.25	1.35
	+		410	428	417	1.22	1.25	1.31
K	—	20	527	474	530	1.19	1.28	1.30
	+		495	508	508	1.16	1.25	1.28
K	—	24	542	560	578	1.26	1.28	1.40
	+		547	560	558	1.28	1.30	1.36
P	—	16	386	480	441	0.203	0.208	0.223
	+		364	430	449	0.193	0.209	0.228
P	—	20	500	521	511	0.192	0.214	0.198
	+		478	507	526	0.191	0.208	0.211
P	—	24	553	556	571	0.164	0.171	0.180
	+		567	541	556	0.169	0.168	0.178
Mg	—	16	436	421	451	0.276	0.240	0.246
	+		416	410	419	0.268	0.272	0.233
Mg	—	20	502	515	516	0.267	0.284	0.294
	+		503	495	512	0.303	0.257	0.301
Mg	—	24	567	548	566	0.212	0.241	0.248
	+		554	551	560	0.257	0.270	0.244

The mean content of other elements at the three sampling dates were as follows :—

		Sampling age in weeks		
		16	20	24
Nitrogen	—	2.19	2.22	2.11
	+	2.15	2.19	2.15
Calcium	—	0.183	0.204	0.171
	+	0.181	0.204	0.184
Manganese (PPM)	—	214	361	294
	+	238	366	305
Iron (PPM)	—	72	67	60
	+	72	74	65

HARVESTING DATA

The main effects of the treatments on Tons cane/acre, Pol % cane, expressed juice purity and parts per million of phosphate in the juice are given in Table IV.

TABLE IV

		K_0	K_1	K_2	P_0	P_1	P_2	Mg_0	Mg_1	Mg_2
T.C.A.	—	57.0	59.3	59.0	47.7	64.5	63.1	59.2	56.1	60.0
	+	57.0	62.4	62.1	54.7	61.9	65.0	61.4	60.1	60.1
Pol %	—	13.50	13.70	14.27	13.59	13.91	13.98	13.65	14.16	13.66
cane	+	13.80	13.45	13.84	13.47	14.06	13.56	13.72	13.25	13.13
Purity	—	83.03	82.74	83.73	83.58	82.99	82.93	83.16	83.86	82.48
	+	83.94	83.32	83.32	83.26	83.86	83.67	82.97	83.26	84.56
Phosphate	—	41.1	33.6	31.0	26.5	33.3	34.6	30.8	29.7	34.0
PPM in juice	+	31.4	36.6	35.5	29.4	34.1	40.1	33.9	37.1	32.6

TWO-WAY TABLES OF TONS CANE PER ACRE

		P_0	P_1	P_2	Mean
Mg_0	—	48·6	65.5	63.5	59.2
	+	54.6	62.4	67.2	61.4
Mg_1	—	41.5	63.3	63.2	56.1
	+	52.5	61.5	65.9	60.1
Mg_2	—	52.8	64.8	62.5	60.0
	+	56.6	61.7	61.9	60.1
Mean	—	47.7	64.5	63.1	58.4
	+	54.7	61.9	65.0	60.5
K_0	—	49.1	62.3	59.6	57.0
	+	50.8	57.0	63.2	57.0
K_1	—	46.7	67.2	64.2	59.3
	+	57.5	64.8	64.5	62.4
K_2	—	47.4	64.1	65.4	59.0
	+	55.7	63.7	67.0	62.1

		Mg_0	Mg_1	Mg_2	Mean
K_0	—	55.6	53.5	62.0	57.0
	+	53.4	57.1	60.5	57.0
K_1	—	63.0	52.9	62.4	59.3
	+	64.5	64.7	58.0	62.4
K_2	—	59.0	62.3	55.6	59.0
	+	69.7	58.4	61.7	62.1

—Without micronutrients ; +With micronutrient amendment.

DISCUSSION OF RESULTS

In the analysis of variance the phosphate response is highly significant (F required 5.14 : F found 88.7) and the potash effect also reaches significance (F found 5.96).

The over-all average effect of micronutrients (+2.1 tons cane per acre) does not reach significance but it is apparent that almost the whole effect of the micronutrients has occurred at the P_0 level (*i.e.*, in the absence of phosphate manuring). The mean response to micronutrients at the P_0 level is +7 tons cane/acre. The effects on quality of the cane are small and of doubtful significance. Phosphate manuring has resulted in a significant increase in juice phosphorus.

TRIAL NO. 3. ALBION ESTATE FIELD ROSE HALL 9, VARIETY B. 4098

This trial differed from the two described above in that a basal treatment of six tons limestone/acre was applied.

The main-effect vegetative growth indices and corresponding analyses are shown in Table V.

TABLE V

Factor	Micro-nutrients	Age (Weeks)	V.G.I. at levels			Mineral analysis of % dry matter at levels		
			0	1	2	0	1	2
K	—	18	435	438	432	1.32	1.30	1.30
	+		421	422	428	1.29	1.29	1.32
K	—	22	419	417	416	1.50	1.54	1.55
	+		416	418	427	1.53	1.51	1.56
K	—	26	461	461	445	1.48	1.49	1.50
	+		451	445	458	1.50	1.50	1.51
P	—	18	415	447	443	0.127	0.140	0.140
	+		399	431	441	0.127	0.132	0.141
P	—	22	408	424	420	0.123	0.137	0.147
	+		392	435	435	0.115	0.136	0.134
P	—	26	461	454	454	0.177	0.172	0.164
	+		447	447	461	0.172	0.186	0.182
Mg	—	18	448	419	439	0.147	0.135	0.135
	+		419	423	429	0.136	0.150	0.152
Mg	—	22	430	417	405	0.154	0.128	0.153
	+		424	417	421	0.153	0.163	0.147
Mg	—	26	470	444	454	—	—	—
	+		451	456	447	—	—	—

The mean content of other elements at the three sampling periods were as follows :—

		Sampling age in weeks		
		18	22	26
Nitrogen	—	1.76	1.47	1.63
	+	1.78	1.45	1.62
Calcium	—	0.139	0.113	—
	+	0.139	0.136	—
Iron (PPM)	—	113	120	—
	+	132	129	—
Manganese (PPM)	—	180	174	—
	+	204	163	—

HARVESTING DATA

The main effects of the treatments on tons cane per acre, Pol % expressed juice and juice phosphorus in parts per million are given in Table VI.

TABLE VI

		K_0	K_1	K_2	P_0	P_1	P_2	Mg_0	Mg_1	Mg_2
T.C.A.	—	49.1	50.4	50.8	47.6	51.5	51.3	49.2	49.1	52.1
	+	51.0	49.0	49.5	48.9	50.6	49.9	50.3	50.3	48.8
Pol %	—	16.65	16.47	16.95	16.66	16.39	17.02	16.61	16.54	16.92
Juice	+	16.66	16.24	16.61	16.63	16.55	16.33	16.70	16.41	16.37
Purity	—	89.89	89.03	89.74	89.42	89.20	90.05	89.23	88.24	91.20
Expressed Juice	+	89.49	87.56	90.07	89.21	89.43	88.49	88.80	89.57	88.79
Phosphorus	—	45.6	50.2	48.7	37.8	44.4	61.4	40.1	58.2	46.3
PPM in Juice	+	48.9	56.4	55.4	37.7	55.7	67.5	61.7	46.3	52.8

TWO-WAY TABLES OF TONS CANE PER ACRE

		P_0	P_1	P_2	Mean
Mg_0	—	46.9	51.2	49.6	49.2
	+	45.4	53.8	51.6	50.3
Mg_1	—	46.1	50.4	50.6	49.1
	+	52.1	49.0	49.9	50.3
Mg_2	—	49.9	52.8	53.7	52.1
	+	49.2	49.0	48.3	48.8
Mean	—	47.6	51.5	51.3	50.1
	+	48.9	50.6	49.9	49.8
K_0	—	43.3	53.6	51.5	49.1
	+	50.0	53.3	49.7	51.0
K_1	—	50.3	50.3	50.6	50.4
	+	48.7	49.6	48.6	49.0
K_2	—	50.2	50.5	51.7	50.8
	+	48.0	48.9	51.5	49.5

		Mg_0	Mg_1	Mg_2	Mean
K_0	—	47.9	48.1	51.3	49.1
	+	52.3	50.3	50.3	51.0
K_1	—	51.2	48.3	51.7	50.4
	+	51.1	50.8	45.1	49.0
K_2	—	48.5	50.6	53.3	50.8
	+	47.4	49.9	51.1	49.5

DISCUSSION OF RESULTS

The field in which this trial was carried out proved to be a representative of soils with limiting physical conditions which are common on parts of Albion and

Rose Hall Estates. The basal dressing of limestone at the relatively high rate of 6 tons per acre has obscured responses that might otherwise have been obtained—since the mean yield of the whole field wherein the trial was carried out was only 33 tons cane per acre, compared to a mean of 50 tons in this trial.

None of the responses obtained reach significance but there is undoubtedly a phosphate response as confirmed by the phosphate levels in the leaf and by the V.G.I.

This phosphate response, however, is only substantial (mean response +6½ tons cane/acre) in the absence of magnesium and in the absence of potassium. No micronutrient effects of any magnitude have shown up in this trial. Quality of cane has not been materially affected but phosphate manuring has quite definitely increased juice phosphorus content.

TRIAL NO. 4. ROSE HALL ESTATE, FIELD TAPPINSBURG 26 B. 37161

This trial received indentical treatments to Trial No. 3.

The main vegetative growth indices and corresponding analytical results are given in Table VII.

TABLE VII

Factor	Micro-nutrients	Age (Weeks)	V.G.I. at levels			Mineral analysis of % dry matter at levels		
			0	1	2	0	1	2
K	—	12	416	412	423	1.61	1.68	1.71
	+		—	—	—	—	—	—
K	—	18	746	717	724	1.46	1.49	1.46
	+		734	729	736	1.41	1.50	1.47
K	—	22	802	806	793	1.44	1 55	1.52
	+		811	802	789	1.44	1.54	1.57
P	—	12	408	417	426	0.167	0.169	0.167
	+		—	—	—	—	—	—
P	—	18	735	725	727	0.160	0.166	0.158
	+		731	730	738	0.166	0.169	0.157
P	—	22	802	785	815	0.153	0.162	0.166
	+		794	797	811	0.154	0.157	0.148
Mg	—	12	428	401	412	0.203	0.209	0.219
	+		—	—	—	—	—	—
Mg	—	18	726	727	734	0.221	0.208	0.208
	+		731	744	724	0.221	0.220	0.226
Mg	—	22	772	815	815	0.164	0.183	0.179
	+		791	812	800	0.189	0.176	0.168

The mean percentage content of other elements in the foliar tissue at the various sampling times were as follows :—

		Sampling age in weeks		
		12	18	22
Nitrogen	—	2.61	2.19	1.95
	+	—	2.15	1.96
Calcium	—	0.213	0.137	0.166
	+	—	0.159	0.178
Manganese (PPM)	—	—	219	147
	+	—	—	157
Iron (PPM)	—	—	84	74
	+	—	—	79

HARVESTING DATA

The main effects of the treatments on tons cane per acre, Pol% expressed juice and phosphate in juice are given in Table VIII.

TABLE VIII

		K_0	K_1	K_2	P_0	P_1	P_2	Mg_0	Mg_1	Mg_2
T.C.A.	—	47.1	46.0	46.5	45.7	46.8	47.0	46.4	46.2	46.9
	+	47.2	46.6	47.6	45.1	46.2	50.2	47.5	47.9	46.0
Pol % juice	—	14.55	15.22	15.20	15.18	15.02	14.76	15.34	14.89	14.70
	+	15 21	15.08	15.20	14.90	15.29	15.30	15.35	15.05	15.08
Phosphate PPM in juice.	—	62.2	59.7	67.0	47.5	72.2	69.1	71.2	57.7	59.9
	+	62.3	61.4	66.6	55.8	70.3	64.0	68.5	71.5	50.3

TWO-WAY TABLES OF TONS CANE PER ACRE

		P_0	P_1	P_2	Mean
Mg_0	—	45.0	48.0	46.2	46.4
	+	44.6	47.4	50.4	47.5
Mg_1	—	44.5	43.6	50.6	46.2
	+	45.8	46.8	51.1	47.9
Mg_2	—	47.6	48.7	44.3	46.9
	+	45.3	44.3	49.3	46.3
Mean	—	45.7	46.8	47.0	46.5
	+	45.2	46.2	50.3	47.2
K_0	—	45.9	48.8	46.6	47.1
	+	44.1	47.2	50.4	47.2
K_1	—	46.0	46.3	45.5	45.9
	+	43.0	50.4	46.5	46.6
K_2	—	45.2	45.2	49.0	46.5
	+	48.0	41.0	53.7	47.6

		Mg_0	Mg_1	Mg_2	Mean
K_0	—	49.3	46.8	45.2	47.1
	+	49.7	47.4	44.5	47.2
K_1	—	48.6	46.0	43.2	45.9
	+	49.7	45.3	44.9	46.6
K_2	—	45.4	45.9	48.2	46.5
	+	43.1	51.1	48.6	47.6

DISCUSSION OF RESULTS

It is apparent that this field was deficient in phosphate but the large basal dressing of 6 tons limestone had been effective in releasing phosphate in an available form. Nevertheless the response to phosphate even following the basal dressing of 6 tons limestone was significant.

An interesting interaction between potash and magnesium has proved significant—it is the reflection of a depressing effect of magnesium on tonnage at low potassium levels and a stimulating effect on growth at the high potassium level, emphasising the importance of suitable potassium magnesium balance in this trial. There is an over-all beneficial effect of micronutrients but it is too small to be of economic significance.

II. SECOND SERIES OF TRIALS—COMBINATIONS OF MAJOR ELEMENTS AND MICRONUTRIENTS.

As mentioned in the introduction the treatments were arranged in the form of a 3 × 3 factorial, the first three factors being (A) 4 cwts./acre sulphate of ammonia, (B) 4 cwts. SA/acre +5 tons/acre limestone, (C) 4 cwts. SA/acre+6 cwts. superphosphate and 1 cwt. muriate of potash and the second three factors being (*i*) controls no treatment, (*ii*) 150 lbs./acre DuPont fritted trace elements, (*iii*) compounded microelement mixture.

TRIAL NO. 1 SKELDON ESTATE VARIETY B. 41227 SECTION 81 FLD. 33

The V. G. I. was determined only once at the age of 4 months and indicated a large response to lime and to the phosphate and potash but little or no response to the micronutrients.

	A	B	C	1	2	3
V.G.I.	332	381	412	371	383	372

Leaf analyses showed N and K values to be adequate but phosphate was deficient.

The yields of cane in tons per acre and Pol % cane are shown in Table IX.

TABLE IX

Micronutrient Factors		Major element factors			
		A	B	C	Mean
1	T.C.A.	47.8	62.0	84.1	64.6
	Pol %	12.38	12.89	12.50	12.59
2	T.C.A.	51.6	65.9	80.8	66.1
	Pol %	12.15	12.47	12.39	12.34
3	T.C.A.	53.9	62.8	83.2	66.6
	Pol %	11.17	13.22	12.64	12.34
Means	T.C.A.	51.1	63.6	82.7	65.8
	Pol %	11.90	12.86	12.51	12.42

DISCUSSION OF RESULTS

The responses due to limestone at 5 tons per acre (+12½ tons cane) and to 6 cwts. superphosphate + 1 cwt. muriate of potash (+31½ tons cane) are highly significant. Whilst not reaching significance there is a definite suggestion that the micronutrients have produced a positive response (+6.1 tons cane/acre) when sulphate of ammonia was the only fertilizer used but has not produced a response in the presence of lime or phosphate. Lime and phosphate have resulted in a significant improvement in quality over the sulphate of ammonia only, but micronutrients have not resulted in any significant change in quality.

TRIAL NO. 2. PORT MOURANT ESTATE FIELD ANKERVILLE 14 VARIETY B. 41227

The treatments applied in this trial were identical in all respects with those described in Trial No. 1.

Leaf samples were collected for the determination of V.G.I. and for analyses at age 18 weeks. These data are presented in Table X, from which it will be seen that nitrogen and potash were adequate but that phosphate was markedly deficient in all the treatments which did not get phosphate fertilizer.

TABLE X

Treatment	A_1	A_2	A_3	B_1	B_2	B_3	C_1	C_2	C_3
V.G.I.	398	408	368	452	419	435	494	463	461
N % dry m.	2.34	2.36	2.31	2.36	2.34	2.30	2.30	2.33	2.43
P % dry m.	0.148	0.145	0.133	0.168	0.159	0.145	0.203	0.190	0.202
K % dry m.	1.17	1.13	1.10	1.22	1.17	1.29	1.31	1.23	1.35

HARVESTING DATA

The yields in tons cane/acre, Pol % cane, juice purity and parts per million phosphate in the juice are summarized in Table XI.

TABLE XI

T.C.A.

	A	B	C	Mean
1	41.8	48.9	58.4	49.7
2	42.0	49.0	49.4	46.8
3	38.0	51.0	46.2	45.1
Mean	40.6	49.6	51.3	47.2

Pol % Cane

	A	B	C	Mean
1	12.97	11.02	10.73	11.57
2	11.52	11.15	11.82	11.50
3	11.88	11.84	12.80	12.17
Mean	12.12	11.34	11.78	11.75

Purity

	A	B	C	Mean
1	82.4	79.8	81.0	81.1
2	80.4	78.8	80.3	79.8
3	80.3	81.4	81.2	81.0
Mean	81.0	80.0	80.8	80.6

Phosphate (PPM in juice)

	A	B	C	Mean
1	60	64	63	59
2	49	70	87	69
3	88	61	67	72
Mean	66	65	69	67

DISCUSSION OF RESULTS

The error in this trial was rather higher than usual and it is probable that the cane was rather over-mature when harvested. The response in yield of cane per acre to lime and to phosphate and potash is, however, highly significant. There is a definite suggestion that the micronutrients may have reduced yields somewhat but the reduction does not reach significance. The quality differences also are not significant.

TRIAL NO. 3. ROSE HALL ESTATE, FIELD ADELPHI 46 B, VARIETY B. 41227

The treatments were identical to those applied in Trials 1 and 2.

The V. G. I. and analysis of samples taken during growth are presented in Table XII.

TABLE XII

3 MONTHS SAMPLES

Treatment	A_1	A_2	A_3	B_1	B_2	B_3	C_1	C_2	C_3
V.G.I.	769	779	824	939	905	1001	1005	1021	1024
N	2.93	2.75	2.93	2.85	2.80	3.10	2.98	3.18	3.18
P	0.174	0.178	0.186	0.195	0.205	0.250	0.308	0.287	0.291
K	1.36	1.44	1.32	1.46	1.36	1.24	1.44	1.40	1.48

TABLE XII (Contd.)

4½ MONTHS SAMPLES

Treatment	A_1	A_2	A_3	B_1	B_2	B_3	C_1	C_2	C_3
V.G.I.	1340	1332	1323	1303	1286	1313	1338	1317	1298
N	2.20	1.90	2.10	2.05	1.95	1.98	2.00	2.10	2.10
P	0.178	0.178	0.186	0.163	0.178	0.170	0.178	0.205	0.178
K	1.30	1.24	1.02	1.40	1.48	1.44	1.18	1.24	1.50

The growth indices indicate a growth response in the early stages (at 3 months) but the differential has largely disappeared at 4½ months. The analyses indicate a slight phosphate deficiency in the plots treated with sulphate of ammonia only. There appears to be an interaction between micronutrients and major elements in their effect on the potash content—the former causing a reduction in leaf potash in the sulphate of ammonia plots (A) but an increase in the phosphate + potash plots (C).

HARVESTING DATA

Weight of cane was determined in this trial but sucrose and purity determinations were not made. The results are given in Table XIII.

TABLE XIII

TONS CANE PER ACRE

	A	B	C	Mean
1	44.5	53.9	56.7	51.8
2	48.2	55.4	55.8	53.6
3	49.2	52.2	55.3	52.2
Mean	47.3	54.2	56.0	52.5

DISCUSSION OF RESULTS

This trial has again shown a significant response to both lime alone and to superphosphate and potash. The effects of micronutrients are not significant but there is here again the suggestion that micronutrients have been beneficial (to the extent of +4.7 tons cane/acre) in those plots which received sulphate of ammonia only but have produced no effect where either lime or phosphate and potash have been applied.

TRIAL NO. 4 UITVLUGT ESTATE, FIELD M.Z. 46, VARIETY B. 4098

The major element treatments in this trial differed from the previous three trials in that treatment C consisted of 4 cwts. of superphosphate +3 cwts. muriate of potash since the trial was located on an estate where the incidence of potash deficiency is as frequent as that of phosphate deficiency and where the latter deficiency is not so severe as in the Berbice district where the first three trials were located. The soil was a silty clay with rather poor structure : the trial was harvested at age 49 weeks.

The yield of cane in tons per acre is shown in Table XIV.

TABLE XIV

TONS CANE PER ACRE

	A	B	C	Mean
1	29.0	38.4	38.3	35.3
2	31.3	39.3	37.0	35.8
3	31.8	36.3	37.5	35.2
Mean	30.7	38.0	37.6	35.4

The response to 5 tons limestone and to the phosphate +potash is highly significant. No other differences were significant. It is of interest, however, that in this trial also there is a slight positive response to the micronutrients when sulphate of ammonia alone is applied but that there is no suggestion of a response in the plots receiving lime or potash and phosphate.

TRIAL NO. 5. UITVLUGT ESTATE, FIELD DE KINDEREN WEST 60 SOUTH, VARIETY B. 47225

Treatments applied in this trial were identical to those in Trial No. 4. Some growth measurements were taken at age 22 weeks : these measurements consisted of (*i*) the length of stalks per specific length of row selected at random in each plot and (*ii*) the total number of stalks per plot.

In Table XV the upper figure is the length of cane per sample length of row in feet and the lower underlined figure is the total number of stalks in the plot.

TABLE XV

	A	B	C	Mean
1	120 1485	140 1660	125 1681	128 1620
2	127 1496	128 1660	148 1699	134 1618
3	138 1718	127 1551	139 1707	132 1659
Mean	128 1566	132 1635	137 1696	

HARVESTING DATA

The yields in tons cane per acre are presented in Table XVI.

TABLE XVI

TONS CANE PER ACRE

	A	B	C	Mean
1	42.5	52.0	46.25	47.0
2	45·2	45.6	52.8	48.0
3	49.25	47.25	48.0	48.2
Mean	45.7	48.2	49.0	47.6

Main effects. L.S.D. 4.7 tons.

DISCUSSION OF RESULTS

The responses of 2.5 tons and 3.3 tons cane per acre to limestone and to potash + phosphate respectively do not reach significance. The variability in this trial has been somewhat high. Although the apparent response to micronutrients in the presence of sulphate of ammonia alone is visible in these results also, it is rendered more uncertain by the anomalous yields in the comparisons between the B series and the C series of treatments.

It is possible that the very high rainfall to which this crop was subjected (188 inches) may have, through its deleterious effects on the soil, been responsible for some of the anomalies in this trial and the resulting failure to draw any conclusions from it.

THIRD SERIES OF TRIALS

8×8 LATIN SQUARES TESTING EFFECT OF LIMESTONE, POTASH AND PHOSPHATE AND MOLYBDENUM.

Molybdenum deficiency was only seen in very acid silty clay highly deficient in calcium, potash and phosphate at Uitvlugt and Wales estates and was accentuated by the use of sulphate of ammonia alone as a fertilizer.

Molybdenum alone whilst causing disappearance of leaf symptoms did not correct the stunted growth since the deficiency of the major elements was dominant. The correction of the major element deficiencies with limestone, superphosphate and muriate of potash on the contrary eliminated the molybdenum deficiency also.

TRIAL NO. 1. UITVLUGT ESTATE, VARIETY B. 4098, FLD. D.K. W. 46

The yield of cane per acre together with duplicate molybdenum assays from representative foliar tissue from each treatment at age 4½ months are given in Table XVII.

TABLE XVII

Treatment Number	Indentity of Treatment	PPM Molybdenum in dry matter (*i*)	(*ii*)	Yield in tons cane/acre
1	S/A only.	0.090	0.10	55
2	S/A+Limestone (furrow).	0.155	0.20	56
3	S/A+Limestone (broadcast).	0.160	0.20	55
4	S/A+Limestone+P+K	0.185	0.22	59
5	S/A+P+K	0.080	0.08	62
6	S/A+Mo	0.360	0.32	57
7	S/A+P+K+Mo	0.500	0.47	59
8	S/A+Limestone+P+K+Mo	0.790	0.73	60

L.S.D. 4.3 tons/acre.

DISCUSSION OF RESULTS

Only the effects of the potash and phosphate dressings reach significance. There is a small but insignificant response of 2 tons cane/acre to the molybdenum in the presence of sulphate of ammonia only.

From this it may be concluded that the adequacy level of molybdenum in the dried chlorophyllous tissue of sugarcane leaves is at or below 0.08 parts per million. Limestone almost doubled the molybdenum content without affecting the yields.

TRIAL NO. 2. ALBION ESTATE FLD. BELVEDERE 5., VARIETY B.37161.

This trial was identical to Trial No. 1 with the exception that ordinary superphosphate was replaced by 1½ cwts. of triple superphospate (47% total P_2O_5 : 54% water soluble P_2O_5).

Yields in tons cane/acre are presented below :—

Treatment	1	2	3	4	5	6	7	8
Yield	37.5	43.8	44.3	43.4	39.3	36.6	37.6	45.3

L.S.D. 3.2 tons/acre

This trial has shown a highly significant response to limestone and a very small response to phosphate but no response to molybdenum. This was not surprising since the molybdenum content of the control plants was 0.35—0.38 ppm in the dry matter.

TRIAL NO. 3. LA BONNE INTENTION ESTATE

Treatments were identical to those in Trial No. 1.

Unfortunately the cane was harvested without warning and so no yield data are available. However, V.G.I.'s had been collected at 3 months, 4½ months, and 6 months and these indicated that if there should have been a yield response to molybdenum it would have been small. The V. G.I.'s and molybdenum assays are recorded in Table XVIII.

TABLE XVIII

Treatment Number	3 months		4½ months		6 months		Mean V.G.I.'s all collection
	Mo ppm	VGI	Mo ppm	VGI	Mo ppm	VGI	
1	0.08	372	0.14	613	0.16	531	505
2	0.25	414	0.29	626	0.30	559	533
3	0.17	375	0.24	621	0.27	558	518
4	0.18	436	0.22	624	0.24	559	540
5	0.08	420	0.14	633	0.14	563	539
6	0.19	399	0.33	637	0.29	554	530
7	0.17	393	0.35	625	0.27	555	524
8	0.20	432	0.55	631	0.50	571	545

These trials indicate that responses to molybdenum are not to be expected if the foliar molybdenum level is 0.08 ppm or more. In the field where the deficiency symptoms occurred the molybdenum content was 0.04-0.05 ppm. A further survey of the molybdenum status has shown that the molybdenum content of cane leaves is substantially higher in the Berbice estates.

GENERAL DISCUSSION OF RESULTS

Sufficient data are now available to indicate that there are no serious micro-element deficiencies in the clay soils of British Guiana. Even where responses to a composite selection of possibly-deficient micronutrients have occurred, such responses have only been obtained when one or other of the major nutrients are in short supply. Obviously good cane husbandry calls for adequacy not only of nitrogenous materials but also of such major fertilizers as lime, phosphate and potash and with the implementation of adequate major element fertilizer policy—all transient inadequacies of micronutrients automatically disappear.

This is presumably because of the tremendous improvement in the root system of sugarcane which occurs on British Guiana clay soils when applications of lime, potash and phosphate are made. A further important factor is the maintenance of good tilth and good drainage without which a prolific root system cannot develop. For example the molybdenum deficiency symptoms occurred on a silty clay which had lost its structure as a result of being harvested in exceedingly wet weather. When the same cane material was uprooted and replanted in the same spot after a good hand-forking the new crop showed none of the symptoms and gave a reasonably average yield of cane. As a result of a complete survey of micro-element levels in sugarcane which has been carried out since the trials described in this paper were laid down, it is possible to speculate as to which elements would have a tendency to approach limiting values under particularly unfavourable conditions. Boron has been found occasionally to be seasonally in short supply, particularly during heavy and continuous rain—leaf values may fall in such periods to 3-4 ppm—but the levels rise very quickly when heavy rainfall abates. Normal levels of boron are 10—25 ppm.

In the Berbice area copper may very rarely approach the critical value of 4-5 ppm : values in the Demerara district are consistently higher (7-9 ppm). No areas of low zinc have been identified.

The three micro-elements that could conceivably become somewhat limiting under unfavourable conditions of growth resulting from high acidity, lime, phosphate and potash deficiency and poor soil structure accompanied by inadequate aeration and water-logging would thus be boron in both Berbice and Demerara ; copper in Berbice only and molybdenum in Demerara only. At present, however, micronutrient deficiencies appear to have no great economic significance in British Guiana Sugarcane soils.

The factorial trials with three levels of K, P and Mg and a further series of 3K × 3P × 3Ca trials not described in the present paper, confirm the large responses to both lime and phosphate on the Berbice estates and to phosphate, potash and lime on the Demerara estates.

On the whole the K × P × Mg trials have not shown any outstanding interactions—being mostly direct responses to potash or phosphate or both, with little effect or sometimes even a slightly depressing effect of magnesium on cane growth and quality. The two cases previously encountered where potash brought about a reduction in growth as a result of a suppression of magnesium uptake were apparently exceptional and undoubtedly enhanced by the high levels of potash used in those trials. In the present series no recurrences of this phenomenon has occurred, although the value of potash in bringing down excessive magnesium levels in the leaf was quite clear.

ACKNOWLEDGEMENTS

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Mr. N. V. Mohan Rao presented the following paper.

Paper

SOME ASPECTS OF NITROGEN NUTRITION OF SUGARCANE IN ANDHRA

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INTRODUCTION

Sugarcane is one of the most important commercial crops in Andhra State and plays a vital role in the agricultural economy of the cultivator. It occupies an area of about 1,20,000 acres and shows indications of further increase ; over 80 percent of the area under cane is occupied by Co. 419. With eight sugar mills having a total crushing capacity of about 5,000 tons of sugarcane per day and producing over 40,000 tons of white sugar annually, the sugar industry has come to stay as the foremost in the State and stands fourth in the Indian Union. While approximately 17 to 18 per cent of the cane grown goes to production of sugar, about 65 to 70 percent is converted into crude sugar made in the form of moulds, called Jaggery or Gur, which finds wide use for domestic consumption in place of sugar and is also exported to a considerable extent.

Manuring is one of the most potent factors to step up yields of sugarcane and forms a major item in its cost of cultivation. Of the three major plant-food elements, sugarcane responds most to nitrogen in this State, no perceptible effects being observed in the case of potash and phosphoric acid. The total dose of nitrogen varies from about 100 lbs. per acre in the northern to about 200 lbs. in the southern and central districts. Taking about 150 lbs. nitrogen per acre as the average for the State, the annual requirement of nitrogenous fertilizer taken as ammonium sulphate works out to about 45,000 tons, involving an expenditure of approximately fifteen million rupees. The need for a scientific and rational schedule of fertilization in the interest of national economy is thus apparent.

Studies were, therefore, directed to elucidate in detail the various biochemical aspects of nitrogen nutrition of sugarcane with particular reference to this tract; the effects of different doses, forms, and times of application of nitrogen on the qualitative and quantitative aspects of sugarcane production are discussed in the following pages. Preliminary studies conducted on the possibilities of the "foliar diagnosis" technique for control of nitrogen fertilization are summarised in a later part of this paper.

SOIL AND CLIMATIC CONDITIONS

Though no systematic and detailed soil survey of the State was conducted, general information about the major soil types and their productive capacity is available (37). Sugarcane is cultivated on almost all types of soils, but the maximum concentration is in the well-drained loams and the fertile alluvial soils in the northern coastal districts of the State ; it is also in this region that all the eight existing sugar factories are situated. In the light, red soils of the Chittoor district, and the heavy black soils of the inland central districts, the entire bulk of the cane grown is converted into gur. The crop is grown under irrigated conditions in the majority of the area. The alluvial delta soils of Godavari and Krishna are fertile and well-supplied in plant nutrients, showing some deficiency of nitrogen ; all other sugarcane soils are more deficient in nitrogen and organic matter. The black soils of the semi-arid inland districts are heavy clays, alkaline in reaction and often suffer from lack of irrigation facilities at present.

The climatic conditions of the State represent a transition from the subtropical Northern India to the hot and humid South ; the distribution of rainfall varies from about 40 to 45 inches in the northern districts to about 20 to 25 inches in the southern and central districts. The rainfall is received in two precise instalments, in the south-west monsoon (June-August) and in the north-east monsoon (October-December). Highest summer temperatures are recorded in the months of April-May, while the dry and chill winter usually lasts from December to February.

The meteorological data for Anakapalle*, the main centre of sugarcane research in Andhra State, are given in Table I.

TABLE I

METEOROLOGICAL DATA—ANAKAPALLE
(Average for the past ten years)

Month	Maximum Temperature °F	Minimum Temperature °F	Relative Humidity %	Rainfall	
				Rain (inches)	No. of rainy days*
January	85.2	61.6	64	0.11	1
February	89.1	65.8	64	0.45	1
March	93.5	70.9	69	0.30	1
April	95.7	76.0	70	1.12	3
May	98.3	80.6	69	2.44	3
June	97.2	80.2	68	3.39	6
July	91.5	77.8	79	6.27	12
August	90.7	77.7	75	6.16	9
September	90.5	76.2	78	7.92	11
October	87.8	73.9	79	8.10	8
November	85.6	69.4	72	2.46	3
December	84.3	62.8	64	0.81	1
			Total for the year	39.53	59

*With a rainfall of 0.1 inch and over.

The soils of the Anakapalle tract are representative of the well-drained loams of the Northern districts ; analysis of the top one-foot soil is given in Table II.

TABLE II

pH	7.2	*Mechanical analysis:*	
Total nitrogen	0.0434%	Moisture	2.96%
Organic carbon	0.42%	Clay	32.87%
Lime	0.46%	Silt	9.63%
Available P_2O_5	0.022%	Coarse and fine sand	54.53%
Exch. calcium	14.4 m. eq. per 100 gm.		
Water soluble salts	0.053%		

Sugarcane is normally planted in the months February-April, and harvested after a year ; after completion of germination and tillering, active growth commences from June and extends till December, coinciding broadly with the monsoons, after which maturity sets in.

REVIEW OF LITERATURE

The role of nitrogen fertilization in the production of sugarcane has received probably the greatest attention in agronomic research on the crop. Earlier work by Das (11), and Das and Cornelison (12) showed that higher nitrogen doses increased elongation, tillering, leaf-width, and succulence of the plant ; while the sucrose per cent in juice was depressed, the glucose, alcohol soluble as well as total nitrogen and the mineral matter in the same showed an increase. Ayres (4) reported that sugarcane absorbed potash and silicon to a much greater degree than nitrogen and phosphorus and this absorption was governed by the stage of development of the plant ; he also found that the highest concentration of these elements in the dry matter of the plant occurred at three months age and that, while the rate of absorption of nitrogen diminished after reaching a maximum by about six months, that of calcium, magnesium, phosphorus and potash continued to increase till a far later age. Kobus (21) reported from Java that nitrogen absorption was most rapid under those conditions upto 8 months of age, followed by a decrease. Borden (6,7,8,9,10) elaborated the studies on nitrogen nutrition of sugarcane in Hawaii; he stated that nitrogen increased the same in all parts of the plant, particularly the foliar tissues and the nitrogen content declined with age. The total green and dry weight of the plants and also the green tops generally increased with higher nitrogen application, the effect of the initial increments of nitrogen being more marked. Nitrogen also depressed arrowing and tended to promote lodging in cane. Borden (5) also reported on the role of climatic conditions, particularly light and temperature, on nitrogen utilisation, stating that deficiency of the same retarded growth. The results from fertilizer experiments conducted in the Dominican Republic and South Africa were recently reviewed by Aughtry et al (3), and Du Toit (14); Innes (19) dealt with the inorganic fertilization practices in the principal Caribbean Islands, while the Arecibo fertilizer experiments in Puerto Rico were discussed by Samuels and Landrau (35).

Manurial experiments on sugarcane in India have been reviewed by Rege (32), and Mukherjee and Verma (28). The highest response in respect of cane yield was from nitrogen in all the cane-tracts, while potash and phosphoric acid were useful in specific regions. The optimum dose of nitrogen was found to vary from less than 100 lbs. per acre in the subtropical North India to over 300 lbs. in the Bombay-Deccan. Summarising the detailed studies on sugarcane nutrition in the Bombay-Deccan, Rege and Basu (33) observed that cane-growth ceased earlier under nitrogen deficiency and that the optimum uptake of nitrogen, phosphoric acid, potash and lime was completed by October to December, about 50 percent of the total uptake of nitrogen being completed before six months. Asana(2) computed from the data of the Hawaiian workers that the highest rate of nitrogen absorption occurred between 3½ to 6 months age of the crop at low and medium doses of nitrogen fertilization. Efficiency of absorbed nitrogen in the matter of dry matter accumulation was stated by Lal (25), to increase with age and nitrogen deficiency, the nitrogen under partially deficient conditions being almost entirely utilised. The role of bulky organic manures in the nutrition of sugarcane was discussed by Lakshmikantam (22), who reported that they did not come to the level of concentrates in respect of nitrogen nutrition ; similar observations were also made by Rege (32). Parthasarathy and Lakshmikantam (30) reviewed the fertilizer experiments with nitrogenous manures on sugarcane in Madras and observed that under low soil moisture conditions, organic nitrogenous manures were better suited, while ammonium sulphate was effective under a comparatively more plentiful water supply.

EXPERIMENTAL DETAILS

Detailed investigations on the influence of graded doses of nitrogen on the uptake of the same by the cane plant, dry matter production and the ultimate yield of cane and sugar were conducted in a field experiment during the years 1948-49 to 1950-51. The layout was one of split-plot design, with two varieties, Co. 527 and Co. 419 as major treatments and three levels of nitrogen top-dressing, viz., 100 lbs., 150 lbs. and 200 lbs. nitrogen per acre as the minor treatments ; each treatment was replicated six times. The nitrogen top-dressing was in the form of a mixture of groundnut cake and ammonium sulphate in 2:1 proportion on nitrogen basis. The cane yields were noted separately for the replications and analysed statistically ; the yield of sugar was computed from analysis of composite juice samples at harvest.

Plant samples (above-ground portion) were drawn by the Unit Length Method, the strips to be harvested periodically for study of nitrogen-uptake being selected by lot from cane rows separately left for the purpose, apart from the rows for recording yields. After taking the fresh weights of stems and leaves, moisture was determined on the same immediately; later, total nitrogen was estimated in oven-dry samples of the plants by the Kjeldahl method (1). To study the effects of the treatments on the soil fertility, analysis of the same was conducted before and after harvest of the crop, adopting the usual analytical methods. (1,31).

Detailed juice analysis for the sugar and non-sugar constituents was conducted on composite samples for the respective treatments, following the procedures given by A.O.A.C. (1), Fort and McKaig (16), Kharin and Smirnova (20), and Spencer and Meade (38).

The data collected are presented and discussed hereunder.

RESULTS AND DISCUSSION

INFLUENCE OF NITROGEN ON CROP PERFORMANCE

(*i*) *Uptake of nitrogen by the crop*:—The data for the nitrogen content of the plant (varieties Co. 527 and Co. 419), as influenced by the different doses of nitrogen are presented in Table III.

TABLE III

NITROGEN-CONTENT OF STEM AND WHOLE-PLANT (% DRY MATTER)
(March-planted crop)

Treatments*		June	July	Aug.	Sept.	Nov.	Jan.	March
Co.527 : 100 N	S	—	0·78	0·65	0·52	0·32	0·34	—
	P	2.11	1·18	0.78	0.87	0.60	0.48	0.42
do 150 N	S	—	0·81	0.89	0.52	0.45	0.35	—
	P	2.13	1.18	1.03	0.87	0.67	0.50	0.42
do 200 N	S	—	0.78	1.03	0.67	0.55	0.49	—
	P	2.31	1.22	1.13	0.96	0.81	0.76	0.46
Co. 419: 100 N	S	—	0.70	0.50	0.35	0.29	0.32	—
	P	1.94	1.21	0.98	0.61	0.52	0.49	0.29
do 150 N	S	—	0.71	0.74	0.37	0.39	0.35	—
	P	2.19	1.10	1.09	0.72	0.58	0.55	0.29
do 200 N	S	—	0.79	1.02	0.38	0.42	0.39	—
	P	2.00	1.09	1.08	0.71	0.62	0.57	0.36

*S : Stems alone ; P : Whole plant.

The nitrogen-content of the stem tended to show a slight increase upto August, especially in the higher nitrogen doses, and later followed the same trend as whole-plant. The nitrogen concentration in the plant was highest in the early stages, the youngest plant having the maximum nitrogen percent dry matter. There was a fall in the nitrogen concentration with age, under all conditions, that at the "boom stage" being most rapid, indicating the rapid utilisation by the growing crop at this stage (Fig. 1). The necessity for maintaining high concentration of nitrogen in the plant in the early stages of growth has often been emphasized (6, 7, 8, 9, 40).

The early-maturing variety, Co. 527, throughout recorded a higher nitrogen-content than the late variety, Co. 419; increasing doses of nitrogenous manure applied resulted in increase of the same in plant though not in the same proportion. Differences in the nitrogen-content of the plant due to the different amounts applied seemed to narrow down considerably by harvest time. The lower nitrogen-content of Co. 419 together with the higher yield recorded by this variety, was taken to bring out its superiority over Co. 527 in respect of efficiency of nitrogen utilisation (Table VI).

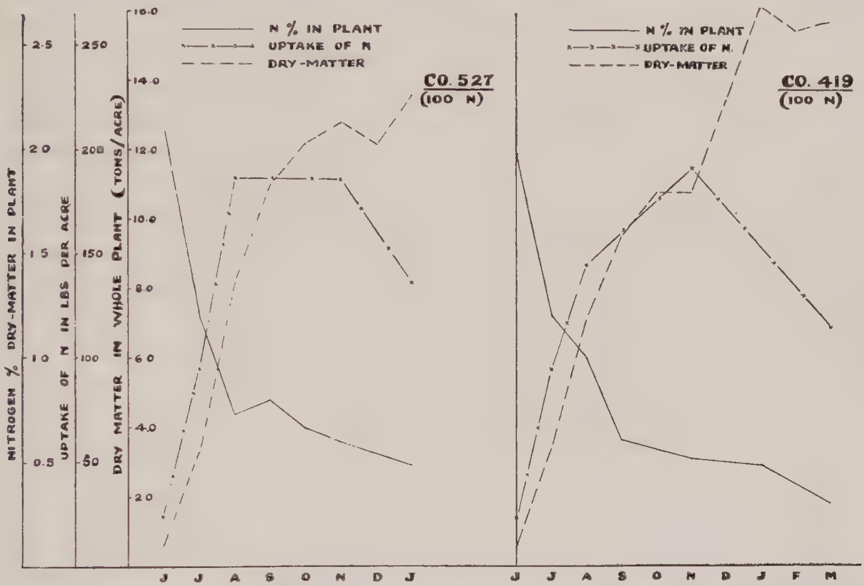

FIG. 1 - PERIODICAL UPTAKE OF NITROGEN AND DRY-MATTER PRODUCTION IN CANE.

From the nitrogen-content of the plant and the weight of plants per unit area, the uptake of the same by the crop per acre was computed and the data presented in Table IV.

TABLE IV

PERIODICAL UPTAKE OF NITROGEN BY THE CROP

(Pounds per acre)

Treatments	June	July	August	Oct.-Nov.	At harvest*
Co.527—100 N	27.7	94.1	187.7	187.9	146.9
do —150 N	34.9	88.3	177.2	217.9	154.1
do —200 N	44.1	112.6	170.2	217.8	188.1
Co.419—100 N	23.5	85.7	146.0	191.5	113.1
do —150 N	36.7	93.4	132.3	167.0	116.0
do —200 N	47.3	112.5	156.1	197.3	125.8

*Co. 527 in January. Co.419 in March.

In spite of the higher nitrogen concentration in the plant, the actual uptake per acre in the early formative stage was the lowest; the nitrogen uptake rapidly increased with the onset of the grand-period of growth (from June), and by about six months age it was found that a major portion of the total uptake was completed (Fig. 1). The weather conditions, with increase in the rainfall and humidity, attended with the favourable temperature at this period could also be seen to be most suitable for rapid growth of the crop (Table I). The maximum uptake of nitrogen was completed by about October-November, whereafter a fall in the same was noted. The period of growth from about 3 to 6 months age of the crop, corresponding to that of the most rapid uptake of nitrogen, appeared to be the most "critical period" from the standpoint of nitrogen nutrition, and a correct manurial schedule should envisage supply of ample amount of available nitrogen to the growing crop during this period. The results of Asana (2) also indicated that the rate of nitrogen uptake increased to a maximum in about 17 weeks after which there was a decline; Rege and Sannabhadti (34) observed that in the Bombay-Deccan the major portion of the nitrogen-uptake was completed by about six to seven months after planting, that of phosphoric acid and potash extending till harvest time.

Higher doses of nitrogen in general resulted in a higher uptake of the same by plant, but the fact that this was not reflected in increased yield indicated the limits to its utilisation by the crop beyond 100 lbs. per acre. An important observation was that the early variety, Co. 527, completed the major uptake of nitrogen earlier than Co. 419, the late variety, other conditions being similar. This pointed to the need for early manuring to early varieties as compared to late ones; actually increased yield without detriment to juice quality was achieved on this Station, with a few low-yielding early varieties, by completing the manuring within two months from planting (23).

(*ii*) *Growth and dry-matter production*:—The rate of growth of the variety Co. 419, as determined by periodical height measurements, under graded doses of nitrogen was studied by Lakshmikantam and Sankaram (24) on this Station; they observed that manuring gave an initial advantage in growth prior to July and that growth (average height) of individual canes was definitely retarded below 100 lbs. nitrogen per acre, doses beyond this resulting in no further improvement.

The periodical variations in the dry-matter production, calculated from the fresh weights of plants per unit area and the moisture content, are shown in Table V.

TABLE V

PERIODICAL ACCUMULATION OF DRY-MATTER IN STEMS AND LEAVES [Tons Per Acre]

[MARCH-PLANTED CROP]

Treatments*		June	July	Augst.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March
Co. 527 : 100 lbs. N	S:	0.63	0.84	2.93	6.04	7.43	9.16	8.06	10.80	—	—
	L:	—	2.47	5.27	4.92	4.78	3.60	4.15	3.80	—	—
do : 150 lbs. N	S:	0.64	1.07	3.04	4.99	7.23	9.83	8.03	10.35	—	—
	L:	—	2.74	5.12	4.10	4.29	3.28	3.93	4.01	—	—
do : 200 lbs. N	S:	0.49	0.90	2.60	4.96	7.83	7.88	7.14	10.16	—	—
	L:	—	2.08	4.01	4.17	4.43	3.17	4.04	3.09	—	—
Co. 419 : 100 lbs. N	S:	0.59	0.89	2.34	5.58	6.28	8.19	10.50	13.20	11.52	12.42
	L:	—	2.41	4.73	3.98	4.52	2.67	3.03	3.08	3.90	3.38
do : 150 lbs. N	S:	0.52	0.62	2.64	6.13	6.11	10.79	10.10	11.65	10.03	10.81
	L:	—	2.81	5.46	4.93	3.04	2.89	2.98	3.58	3.92	3.50
do : 200 lbs. N	S:	0.82	1.15	2.87	6.49	8.05	11.38	10.35	15.37	10.44	10.12
	L:	—	3.04	4.35	4.86	3.90	3.17	3.28	3.00	2.96	3.81

*S : Stems, L: Leaves.

The data disclosed that the most rapid increase in the dry-matter accumulation in stems occurred from August to November for both the varieties ; this was almost in succession to the period of most rapid uptake of nitrogen and indicated immediate utilisation of the same for plant growth. No clear differences in the dry-matter production in respct of leaves could be seen. Similar results were reported by Rege and Sannabhadti (34), who found that nutrient absorption took place at a much greater rate than the elaboration of dry-matter in the early states of growth. Co. 419 showed a further accumulation of dry matter even upto January, which must have contributed to its higher yield. Higher doses of nitrogen tended to increase the dry matter production of Co. 419 only in the early stages, while the effects on Co. 527 were not marked.

The moisture-content of plants was highest in the active growing period and declined towards maturity, that for Co. 527 being still earlier. Higher doses of nitrogen resulted in a slight increase of plant-moisture. Co. 527 was found to record almost throughout a lower moisture-content than Co. 419 and as reported by Parthasarathy and Ramarao (29), this might have induced its earlier maturity. A study of the ratio of fresh weights of stems to leaves at periodical intervals disclosed a progressive increase till harvest, as reported by Dillewijn (13), Co. 419 exhibited throughout a higher ratio than Co. 527, this being consistent with the higher rate of stem-production in this variety and its higher moisture. The effects of the different nitrogen doses were found to be erratic.

(*iii*) *Cane and sugar yields* :—

The yield of cane and sugar calculated per acre are given in Table VI, being average for the three seasons, 1948-49 to 1950-51; a summary of the results of statistical analysis of the cane-yield data for the three years is also presented in the same table.

TABLE VI

YIELD OF CANE AND SUGAR (Average for 3 years)

Treatments	Yield in tons per acre		No. of stalks per acre	Yield in tons per lb. of N top-dressing	
	Cane	Sugar		Cane	Sugar
Co. 527 -100 lbs. N	41.09	4.13	40,560	0.411	0.0413
-do- -150 lbs. N	43.38	4.56	43,050	0.289	0.0304
-do- -200 lbs. N	42.73	4.03	42,890	0.214	0.0202
Co. 419 -100 lbs. N	46.15	5.34	31,780	0.462	0.0534
-do- -150 lbs. N	46.59	5.21	32,150	0.311	0.0347
-do- -200 lbs. N	43.41	4.80	30,580	0.217	0.0240

TABLE VI (Contd.)

Analysis of cane-yield data

	S. E. of treatment mean	Critical difference (P=0.05)	Significance
Major treatments			
(Two varieties)			
1948-49	1.36 tons	4.94 tons	No
1949-50	1.16 ,,	4.22 ,,	Yes
*1950-51	0.59 ,,	2.14 ,,	Yes
Minor treatments			
(Three N-levels)			
1948-49	1.38 ,,	4.08 ,,	No
1949-50	1.41 ,,	4.17 ,,	No
*1950-51	0.74 ,,	2.19 ,,	No

*Analysis by co-variance.

Co. 419 recorded on average higher girth and length of individual canes, though the average internodal length was more for Co. 527. The nitrogen-effects were not so marked except for a slight-increase in length of cane, with higher manuring. Co. 527 had a higher stalk-population per acre at harvest than Co. 419.

The late variety, Co. 419, gave significantly higher yield of cane over Co.527 in two out of the three seasons; the three levels of nitrogen, viz., 100 lbs., 150 lbs., 200 lbs., nitrogen per acre did not differ significantly in respect of cane-yields. The recovery of cane and sugar per pound of nitrogen top-dressing was higher for Co. 419. The lower yield of cane and sugar per pound of nitrogen top-dressing in the case of the higher doses above 100 lbs. per acre indicated the futility of the same from the economic standpoint. In view of this, as also due to lack of response by way of increased outturn, the dose of 100 lbs. nitrogen per acre was taken to be the optimum economic dose for this tract and this was in conformity with the earlier results of Lakshmikantam and Sankaram (24) on this Station.

(*iv*) *Soil analysis* :—

Analysis of the top one-foot soil at the start and after harvest of the crop was conducted during all the seasons. As reported by the authors earlier (27), there was no depletion of nitrogen beyond the initial level under any of the treatments and while the soil reaction (pH) and available phosphoric acid were apparently unchanged, the organic carbon tended to show an increase after cane.

INFLUENCE OF NITROGEN ON THE COMPOSITON OF THE JUICE.*

While the effects of nitrogen fertilization on the yield aspects of sugarcane have been studied in great detail as reported earlier, comparatively less information is available on its effects on juice composition. This is of particular importance to Indian conditions, where a large portion of the cane grown goes to the manufacture of gur. Unlike in sugar manufacture, where clarification of the juice is a well-controlled chemical process, gur-making is comparatively crude and no facilities exist for an efficient removal of the impurities from the mother liquor. An understanding of the occurrence and elimination of the so-called non-sugar impurities in juice thus poses as a major problem from the standpoint of gur. Studies conducted on different aspects of nitrogen fertilization to sugarcane in relation to juice composition are broadly discussed hereunder, the variety under study being Co. 419 throughout.

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*The data for this section have been omitted, but diagrammatically presented in Fig. 2.

(*i*) *Graded doses of nitrogen* :—

The effects of 100 lbs., 150 lbs. and 200 lbs. nitrogen on the composition of the juice of Co. 419 at twelve months age was studied in detail. The data revealed a depression in the sucrose and an increase in glucose and organic non-sugars in juice in the higher nitrogen doses, particularly 200 lbs. per acre. Though the nitrogen doses did not produce any differential effect on the total ash and lime, the phosphate content was depressed and an increase in nitrogen was noted in the higher doses, thereby giving higher values of $N/P_2 0_5$ ratio for the same (Fig. 2A). The depression of phosphate in juice under higher doses of nitrogen beyond optimum has been reported by Borden (9,10), Rege and Basu (33) and Evans (15). These were noted to be detrimental to efficient clarification of the juice, resulting in gur of poorer colour and structure, which was more marked under 200 lbs. nitrogen dose. The effects of nitrogen on the physical characteristics, chemical composition and the keeping qualities of gur were discussed by the authors earlier (26).

(*ii*) *Different forms of nitrogen* :—

The effect of the following forms of nitrogenous manures all applied to supply 100 lbs. nitrogen per acre, on the detailed composition of the juice of Co. 419, was studied :—

1. Ammonium sulphate. (A.S.)
2. Groundnut cake (G.N.C.)
3. Mixture of ammonium sulphate and groundnut cake in proportion of 1 : 2 on nitrogen basis. (Mix.)
4. Farmyard manure. (F.Y.M.)

The "farmyard manure" treatment gave better juice quality as compared to the concentrates and even among the latter, lower purity and higher glucose were recorded wherever ammonium sulphate was used. The inorganic fertilizer, ammonium sulphate, was noted to increase the non-protein as well as total nitrogen and colloids in the juice, while the phosphate was depressed. On the other hand, the bulky organic manure gave the highest phosphate, lowest nitrogen and colloids (Fig. 2B). Thus the N/P_20_5 ratio, which was known to affect gur quality, was lowest for "farmyard manure" and higher wherever ammonium sulphate was included. In conformity with this, the best quality gur was recovered from juice under the farmyard manure treatment.

The cane-yields, however, were significantly higher for the concentrates, as compared to "farmyard manure", indicating the poorer nitrogen supplying capacity of the latter (Table VIII). The need for a combination of organic and inorganic nitrogen for recovery of best quality gur was thus indicated.

(*iii*) *Time of application of nitrogen* :—

The effects of application of nitrogen at different stages of crop-growth on juice composition was also studied, the fertilizer being applied in the form of ammonium sulphate.

The following were the treatments :—

1. A: 50 lbs. N at 1½ months and 50 lbs. N at 3 months.
2. B: 50 lbs. N at 1½ months and 50 lbs. N at 4½ months.
3. C: 50 lbs. N at 1½ months and 50 lbs. N at 6 months.
4. D: 50 lbs. N at 3 months and 50 lbs. N at 4½ months.
5. E: 50 lbs. N at 3 months and 50 lbs. N at 6 months.
6. F: 50 lbs. N at 4½ months and 50 lbs. N at 6 months.

In general, better juice quality was recorded when the manuring was completed by three months. One interesting observation noted was that, while late

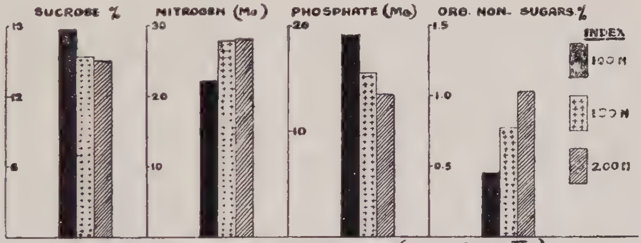

FIG 2A - GRADED DOSES OF NITROGEN (VIDE TABLE V)

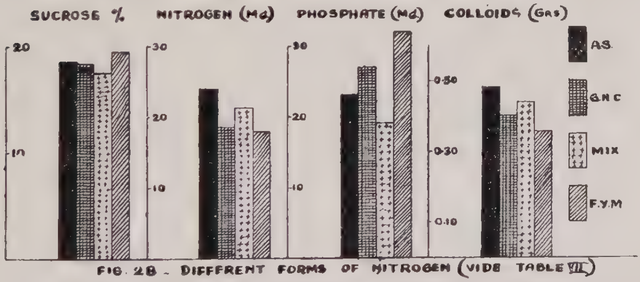

FIG. 2B - DIFFRENT FORMS OF NITROGEN (VIDE TABLE VII)

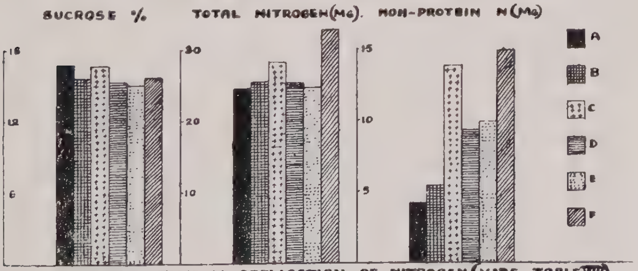

FIG 2C - TIME OF APPLICATION OF NITROGEN (VIDE TABLE VIII)

FIG 2 - EFFECTS OF NITROGEN ON JUICE COMPOSITION (VARIETY Co 419)

applications of nitrogen were known to depress sucrose in juice, very late manuring, viz., at six months after planting did not appreciably lower the sucrose and purity or increase glucose-content, even to the extent of application at 4½ months. Similar findings were reported by Lakshmikantham (23) on this Station and by Evans (15) in Mauritius. This is brought out further by the relative amounts of non-protein and total nitrogen in the juice. The delayed nitrogen dressings resulted in higher non-protein nitrogen in the juice; and the application at 6 months was found to correspond to the highest accumulation of this constituent, which was almost half of the total nitrogen (Fig. 2C). This seemed to indicate that the nitrogen from such late applications tended to remain at lower stages of protein metabolism and for this reason, did not interfere in normal maturation of the crop, brought about by other environmental factors. Evans (15) also found that a "late heavy dressing" of nitrogenous fertilizer, did not produce any significant difference in the sucrose, as compared to the normal dressing, while there was a three-fold increase in the nitrogen content of juice.

FERTILIZATION CONTROL

The foregoing studies thus indicated the importance of optimum nitrogen fertilization to cane at the proper time, from the standpoint of cane production as well as juice quality and pointed to the need for a proper fertilization control. Pioneering work in many sugarcane-growing countries, particularly Hawaii, showed the green leaf portion of the cane plant to be the most representative part for diagnosing its nutrient status and as a guide for fertilization. Innes (18) reported on a survey of the fertility status of some of the cane plantations in Jamaica through a regular leaf-nutrient study. Yuen and Hance (40) and Borden (6, 7, 8, 9, 10) in Hawaii, Halais (17) in Mauritius, Samuels et al (36) in Puerto Rico, and Innes (18) in Jamaica described the foliar diagnosis techniques adopted in those countries. While the third to sixth leaves from apex are sampled for controlling nitrogen fertilization in Hawaii, the third leaf is chosen for the test in Mauritius and Jamaica where the cane is of a much shorter duration than Hawaii.

In the present study also, the third leaf was chosen as the unit of study; the lamina portion at about the middle of the leaf was sampled and the total nitrogen determined on oven-dried material by the Kjeldahl method (31). The fertilization in all cases, except where the actual time of application was under study, was completed by three months after planting. The crop was sufficiently irrigated following manurial dressing, and the sampling was confined to early morning hours. Co. 419 was the variety under study throughout. In the light of the observations reported earlier on the periodical uptake of nitrogen by the crop and the variation of nitrogen concentration in the leaf with age, the period from about four to six months age of the crop appeared to be the most optimum for diagnostic purposes. The salient features of the experiments conducted are discussed hereunder.

(*i*) *Doses of nitrogen* :—

Variations in leaf (punch)-nitrogen under graded doses of nitrogen applied, viz., 0 lb., 100 lbs., 200 lbs., and 300 lbs. per acre were studied during the years 1950-51 to 1952-53, the layout being one of randomised block with four replications. Leaf-nitrogen was estimated at periodical intervals and the yield of cane and juice quality recorded at harvest. The results are summarised in Table VII.

TABLE VII

LEAF-NITROGEN UNDER GRADED DOSES APPLIED (Co. 419)

(Averge for 3 seasons)

Nitrogen dose	Yield per acre		Leaf nitrogen percent dry matter					
	Cane (tons)	Sugar (tons)	3rd month	4th month	5th month	6th month	7th month	Harvest
0 lb. N	35.51	4.55	1.80	1.79	1.71	1.72	1.54	1.17
100 lbs. N	45.41	5.46	2.02	2.03	1.88	1.82	1.69	1.36
200 lbs. N	44.24	4.86	2.14	2.08	1.97	1.94	1.72	1.51
300 lbs. N	46.42	5.02	2.27	2.25	2.07	1.95	1.82	1.51

Differences in leaf nitrogen as affected by the manurial treatments began to manifest only from the third month onwards; this was also the case in respect of external appearance of the plants. The data disclosed a general increase in the leaf-nitrogen with increase in the dose of nitrogen applied, almost throughout the period of crop-growth. There was a marked increase in yield of cane from "no manure" (0 lb. N) to 100 lbs. nitrogen per acre. Further increase in the nitrogen-dose, however, did not produce increased yield. Earlier studies also showed 100 lbs. nitrogen per acre to be the economic optimum dose for this tract. On this basis, the data indicated that the leaf-nitrogen corresponding to this dose might be tentatively taken as the optimum for securing normal cane-tonnage, there being no other limiting factors affecting yield ; for the fourth month age of the crop, this was 2.0 to 2.1% dry matter, values above this representing luxury levels (Fig. 3A).

(*iii*) *Forms of nitrogenous manures* :—

The data on leaf-nitrogen and yield of cane and sugar as influenced by different forms of nitrogenous manures are presented in Table VIII, being averages for the two seasons, 1951-52 and 1952-53.

The treatments, ammonium sulphate, groundnut cake and their mixture recorded significantly higher yield of cane over "farmyard manure" and "no manure" treatments, though the manures were all applied to supply 100 lbs. nitrogen per acre in the case of the treatments 1 to 4. This indicated the comparatively

TABLE VIII

LEAF-NITROGEN UNDER DIFFERENT FORMS OF NITROGEN (CO. 419)
(Average for 2 seasons)

Details (100 lbs. nitrogen)	Yield per acre Cane (tons)	Yield per acre Sugar (tons)	Leaf nitrogen percent dry matter 3rd month	4th month	5th month	6th month	Harvest
Ammonium sulphate	39.41	5.21	2.16	1.99	1.79	1.79	1.41
Groundnut cake	38.65	5.43	2.06	1.99	1.94	1.81	1.21
*Mixture	39.23	5.15	2.08	2.01	1.93	1.79	1.42
Farmyard manure	29.85	4.30	1.79	1.57	1.52	1.42	0.88
No manure (0 lb. N)	26.14	3.86	1.76	1.53	1.46	1.36	0.77

*Mixture of ammonium sulphate and groundnut cake in 1 : 2 proportion on nitrogen basis.

poorer nitrogen-supplying capacity of farmyard manure, as reported by Rege (32). There was a sharp increase in the leaf-nitrogen under the concentrates over

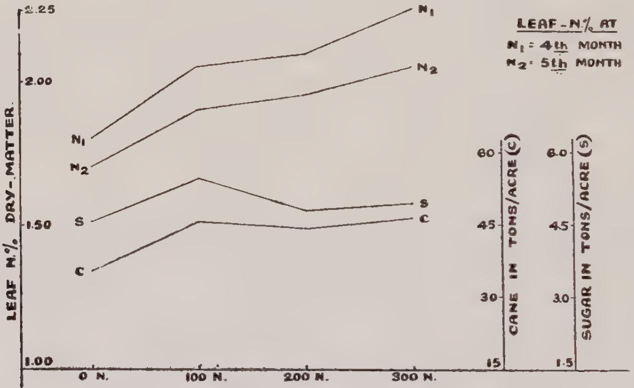

FIG.3 A- GRADED DOSES OF NITROGEN.

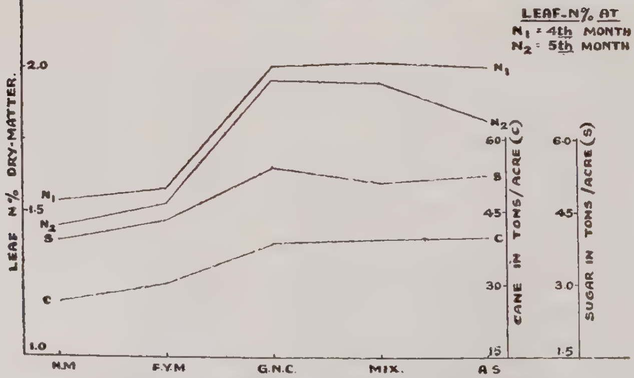

FIG.3B. DIFFERENT FORMS OF NITROGEN

FIG. 3 - LEAF-NITROGEN AND YIELD OF CANE AND SUGAR
(VARIETY- Co 419)

"farmyard manure" and "no manure" treatments, while the three concentrates did not differ much among themselves in respect of leaf-nitrogen (Fig. 3B).

Taking the yield from the concentrates at 100 lbs. nitrogen level as the optimum, the corresponding leaf-nitrogen values were taken to represent the optimum for the particular ages of the crop and these were noted to be similar to those under graded doses reported earlier. The corresponding figures for "farmyard manure" treatment were taken to indicate deficiency values ; at the fourth month these were about 2.0% for optimum and 1.6% for deficiency conditions.

Preliminary examination of the leaf-nitrogen data for the different years indicated that under optimum and below optimum conditions the leaf-nitrogen values throughout the growth period were highly correlated with cane-yields, while with excess doses it was not so.

(*iii*) *Time of application of nitrogen* :—

The variations in leaf-nitrogen as influenced by the time of application of nitrogen were also taken up for study as it is in vogue in some parts of the State to apply large doses of nitrogen to cane with the expectation of the normal returns. The data are given in Table IX.

TABLE IX

LEAF-NITROGEN FOR DIFFERENT TIMES OF APPLICATION OF NITROGEN

(Co. 419—March-planting)

Nitrogen at 100 lbs. per acre applied as	Yield in tons per acre		Leaf nitrogen per cent dry matter				
	Cane	Sugar	June	Aug.	Sept.	Nov.	Harvest
50 N at 1½ months & 50 N at 3 months	41.94	5.03	2.20	2.17	2.00	1.69	1.37
50 N at 1½ months & 50 N at 4½ months	41.55	4.50	2.30	1.93	2.02	1.80	1.36
50 N at 1½ months & 50 N at 6 months	41.39	4.93	2.30	2.01	1.89	1.80	1.34
50 N at 3 months & 50 N at 4½ months	40.56	4.39	1.96	2.22	2.11	1.83	1.27
50 N at 3 months & 50 N at 6 months	40.23	4.17	1.96	2.12	2.08	1.90	1.51
50 N at 4½ months & 50 N at 6 months	38.82	4.29	1.96	1.87	1.57	1.79	1.38
No manure (0 lb. N)	34.72	4.32	1.96	1.87	1.58	1.48	1.22

The data indicated that the highest leaf-nitrogen was recorded when the manuring was completed by three months ; the rise in leaf-N after the manuring was considerably lower as the time of application was delayed. There was a comparatively lower response to the dose given at six months, more so if the plant was altogether starved for nitrogen till late (4½ months). The trend of the cane-yield for the respective treatments was also similar. Though the yields of cane did not differ significantly for the times of application, higher yield was in general recorded when the total dose was given by 4½ months, while the dose given at six months was least effective in pulling up the yield. The data indicated that if for any reason manuring was to be delayed, it would be more useful to give at least a part dose in the early stages for better utilisation of later application, than starving the crop altogether for nitrogen till late in the season.

SUMMARY

(1) Sugarcane responds most to nitrogen in Andhra State, the optimum dose varying from about 100 lbs. to 200 lbs. nitrogen per acre. The effects of different doses, forms and times of application of nitrogen on the uptake and utilisation of the same by the crop and on the composition of the juice are discussed in the paper. The results of preliminary studies on the variations in foliar-nitrogen under these conditions are also outlined.

(2) In the studies on Co. 527 and Co. 419, manured at 100 lbs., 150 lbs., and 200 lbs. nitrogen per acre, it was noted that the nitrogen content of the plant increased with increased doses. This was highest in the early stages and gradually declined with age, the fall at "boom stage" being most rapid. Among the two varieties, Co. 527 recorded a higher nitrogen in plant than Co. 419, which, however, was found to be more efficient in the utilisation of nitrogen for growth.

(3) Uptake of nitrogen by the crop per acre was lowest in the formative stage and was completed by about October-November again showing a decline by harvest time. The most rapid rate of nitrogen-uptake occurred from 3 to 6 months age of the crop, which represented the "critical period" for nitrogen-requirement. The early variety, Co. 527, was found to complete the maximum uptake of nitrogen earlier than Co. 419. The rate of dry matter accumulation in the plant was highest in the period immediately following that of rapid nitrogen-uptake. Co. 419 gave significantly higher cane-yield than Co. 527, but the three levels of nitrogen did not differ in respect of the same. Considering the lower yield of cane and sugar per pound of nitrogen-topdressing beyond 100 lbs. per acre, as also lack of response by the crop, this was taken to be the economic optimum dose for the tract.

(4) In the studies on the effect of nitrogen on the composition of juice of Co. 419, higher doses beyond optimum depressed the sucrose, increased glucose, organic-non-sugars and nitrogen in juice; while the total mineral matter was unaffected, the phosphate content was lowered, which was detrimental for good clarification in gur-making. Among the forms of nitrogenous manures tried, farmyard manure gave better juice quality than concentrates, recording the highest purity, highest phosphates and lowest non-protein and total nitrogen. The reverse was the case wherever ammonium sulphate was included, thus indicating the need for a proper combination of organic and inorganic nitrogen for quality of gur.

(5) In the studies on the effect of the time of application of nitrogen on the

juice composition of Co. 419, better quality was observed when manuring was completed by 3 months ; as the nitrogen application was delayed there was higher accumulation of non-protein and total nitrogen in juice, the highest amount of non-protein N corresponding to the application at six months. However the sucrose-content in juice was not appreciably depressed in the case of the nitrogen application at six months, probably because the nitrogen was not fully metabolised and remained in lower stages of protein-building.

(6) The importance of optimum manuring to cane at proper time, from the standpoint of both yield and composition of juice, being thus apparent, attempts to use the foliar diagnosis technique to judge the nutritional status of the plant are outlined and the preliminary studies with Co. 419 are summarised.

(7) A general increase in leaf-nitrogen with increasing doses applied was noted. There was a marked increase in cane yield from 0 lb. to 100 lbs. nitrogen per acre, but further increase in nitrogen dose did not result in higher tonnage. The leaf-N corresponding to 100 lbs. N per acre (about 2.0-2.1% at the fourth month) appeared to be optimum for securing normal yields. Application of nitrogenous concentrates like ammonium sulphate resulted in a much higher leaf-nitrogen than bulky organic manure (farmyard manure), which recorded significantly lower yield. The leaf-N values for "farmyard manure" treatment (about 1.6% at the fourth month) indicated deficiency level. Leaf nitrogen in early growth period was highly correlated with cane yield under optimum or below optimum conditions of nutrition.

(8) Application of the total dose of nitrogen within three months after planting gave the highest leaf-nitrogen (Co. 419). There was a comparatively lower uptake of nitrogen (response in the leaf-N) from the dose given at six months more so if the plant was altogether starved for N in the early stages. The trend of cane-yields was also similar, the delayed dose of nitrogen given at six months being least effective in pulling up the cane-yield.

ACKNOWLEDGEMENT

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Mr. K. L. Khanna presented the following paper

Paper

STUDIES ON THE MANURIAL RESPONSES OF SUGARCANE ON CULTIVATORS' FIELDS IN BIHAR

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K. P. Singh

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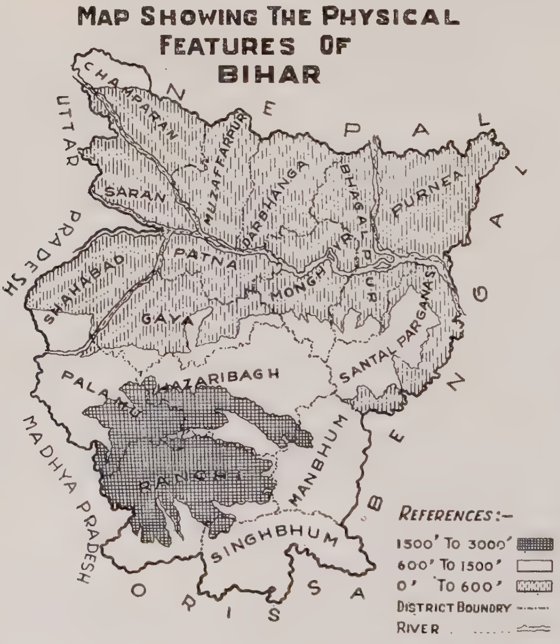
INTRODUCTION.

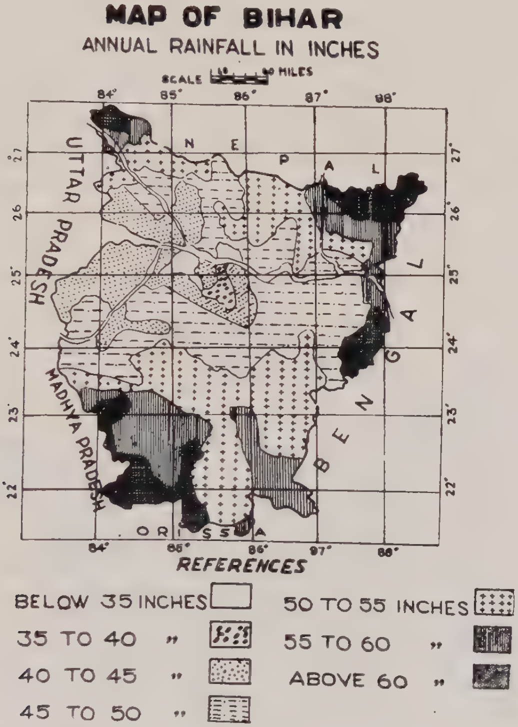
Lying between latitudes 22° and 27° N and longitudes 83½° and 87°E, the State of Bihar consists of two distinct physiographic units, viz., the Indo-Gangetic alluvial plains extending over North and South Bihar and the table lands of Chotanagpur with an average altitude of 2,000 ft. above sea level. Bihar proper is dissected into two nearly equal halves by the river Ganges. The State has a typically monsoon character. An intensely dry summer during the months of April, May and June is followed by the monsoon which generally

PLATE I


Map Showing The Physical Features Of Bihar
Nepal
Uttar Pradesh
Champaran
Saran
Muzaffarpur
Darbhanga
Bhagalpur
Purnea
Bengal
Shahabad
Patna
Monghyr
Gaya
Santal Parganas
Palamau
Hazaribagh
Manbhum
Ranchi
Singhbhum
Madhya Pradesh
Orissa
References:–
1500' To 3000'
600' To 1500'
0' To 600'
District Boundry
River

breaks by the middle of June and lasts till the end of September, bringing in a rainfall of about 40 inches on an average and accounting for about 90 percent of the total annual precipitation. Zonal variations are, however, considerable, the Himalyan Valley and the northern half of Bihar enjoying a comparatively higher annual rainfall (about 30 inches higher than in the Southern portion). Lower rainfall and humidity prevail in the drier regions of the Sone Valley. In the highlands of Chotanagpur precipitation is considerably higher (Plate II). Cold weather sets in about the beginning of November and minimum temperatures go down to 45°F or even below, the lowest temperatures being obtained between mid-December and end January. Slight showers are common during winter but frosts are rare. As temperature falls, there is considerable condensation of atmospheric water vapour as dew and humidity is lowered. With the onset of summer in March a dry and hot season prevails which, assisted by the strong dry westerly winds of April, dries up the soil to a considerable depth.

PLATE II

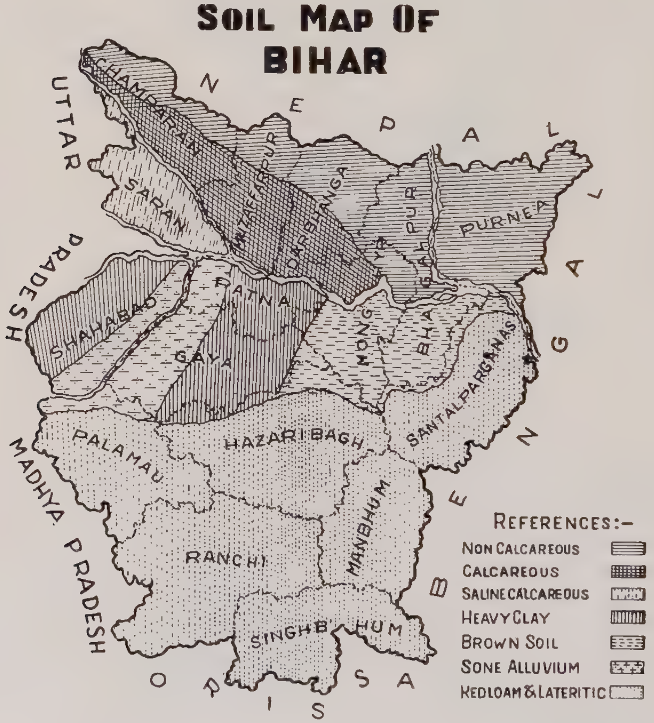

MAP OF BIHAR
ANNUAL RAINFALL IN INCHES
SCALE MILES
84° 85° 86° 87° 88°
27° 26° 25° 24° 23° 22°
NEPAL
UTTAR PRADESH
BENGAL
MADHYA PRADESH
ORISSA
REFERENCES
BELOW 35 INCHES
35 TO 40 "
40 TO 45 "
45 TO 50 "
50 TO 55 INCHES
55 TO 60 "
ABOVE 60 "

Six zonal soil divisions have been recognised in the State, each occupying extensive areas (Plate III). These are :—

(1) **Non-calcareous :** This division is found in the more humid regions enjoying a rainfall of 55-60 inches and covers the major portion of North Bihar,

extending from the Sumeshwar valley at the foot of the Himalayas in the North West to the extreme South East and comprising the northern halves of Champaran, Muzaffarpur and Darbhanga districts as also the entire district of Purnea. These soils vary from grey brown to dark brown in colour at the surface and show good physical condition, open and porous structure and satisfactory drainage. Profiles are characterised by leaching of soluble salts, mobility of phosphates and calcium and mechanical translocation of finer particles. Organic matter status as also available N and P contents are low, C/N ratio being slightly below normal. Reaction is on the alkaline side of neutrality but towards the extreme north, a tendency to development and intensification of acidity is apparent as a result of heavy leaching of bases.

PLATE III


Soil Map Of
BIHAR
NEPAL
UTTAR PRADESH
CHAMPARAN
SARAN
MUZAFFARPUR
DARBHANGA
PURNEA
BHAGALPUR
SHAHABAD
PATNA
GAYA
MONGHYR
BHAGALPUR
SANTALPARGANAS
PALAMAU
HAZARIBAGH
MANBHUM
RANCHI
SINGHBHUM
MADHYA PRADESH
ORISSA
BENGAL
References:–
Non Calcareous
Calcareous
Saline Calcareous
Heavy Clay
Brown Soil
Sone Alluvium
Redloam & Lateritic

(2) **Calcareous**: This division is found in the zone of lower rainfall (40-45 inches) and covers the whole of Saran, the southern portions of the districts of Champaran and Muzaffarpur besides a portion of Darbhanga. These soils are chalk coloured, often tinged grey at the surface, the profiles being characterised by high contents of free calcium carbonate and often showing accumulation zones and concretionary formations. Leaching of soluble salts is less pronounced,

native phosphates being high and stable. There is little evidence of mechanical illuviation. Structure is open and porous with very satisfactory drainage conditions. Soil reaction is highly alkaline (8.2—8.4). As a result of this and also on account of the high free calcium carbonate content, availability of phosphates and activity of micro-elements are restricted. C/N ratio is rather narrow, organic matter status being low and nitrogen reserve poor. In the more arid regions of the district of Saran, intra-zonal soils, locally known as *Usar* or unproductive soils, have developed and these are characterised by a high accumulation of soluble salts in the profile (chiefly sodium). Occasionally, these accumulations may assume proportions enabling the (alkali cation) to affect the exchange complex. This is indicated by a deflocculated condition of the soil and high pH values of 8.8-9.2 or above. C/N ratio is wide and nitrogen reserve extremely low.

(3) **Heavy clay:** Heavy clay soils occur to the south of the Ganges and cover the districts of Patna, Gaya and a part of Shahabad. The soils are dark grey at the surface with profiles characterised by a high content of clay distributed almost evenly through the entire depth. Leaching of soluble salts is extremely restricted, mechanical translocation of materials being almost entirely absent. Physical condition is far from good, drainage characters being highly unsatisfactory. C/N ratio is wide, due chiefly to a low nitrogen level. Available phosphates are comparatively higher. Soil reaction is on the alkaline side of neutrality.

(4) **Sone alluvium:** This division occurs in the valley of the Sone in Shahabad and part of Patna district in South Bihar. Three types are found, viz., sand, sandy clay and clay, representing admixture in varying proportions of the coarse sandy deposits of the Sone and heavy Gangetic alluvium. No evidence of mechanical illuviation has been obtained although leaching of soluble salts is apparent. Distinctive of these soils in a tendency to mobilisation of sesquioxides with organic carbon, specially in the lighter sections—a process analogous to podsolisation. Soil reaction, however, is alkaline. C/N ratios progressively narrow down from normal in sandy to very low in clay type. Available phosphates are medium and nitrogen reserve low.

(5) **Brown soils:** These occur mostly in the portions of Bhagalpur and Monghyr districts lying to the south of the Ganges and vary in colour from brown to reddish brown, with profiles exhibiting abundant brown mottlings and patches. These soils have developed under conditions of intense silicate weathering with restricted leaching. Aluminium is also mobile and the residual soil is rich in oxides of iron. Organic carbon is stable in the surface horizon and mechanical translocation of finer particles absent. C/N ratio is variable, being generally on the low side. Nitrogen reserve is poor and available phosphates very low.

(6) **Red loams** : Red loams occur in the whole of Chotanagpur division. The climate here is more humid owing to heavier rainfall and the close cover of a deciduous forest. During spring, the trees shed leaves and in the summer that follows, there is an intense evaporation and the thin soil layer is dried out completely. This probably accounts for the frequent occurrence of concretionary deposits of varying sizes. The base status is very low, but the reaction as

measured by pH values is not so acidic as might be expected, a circumstance attributable to the sesquioxide character of the clay complex. There is no marked alluviation and the structure is generally friable and granular. Carbon/Nitrogen ratio is narrow, available nitrogen and phosphates being very low. Response to nitrogen is positive and high. Added phosphates undergo irreversible fixation as highly insoluble form and aluminium phosphates.

The conditions of cane growing are unique in North Bihar in that the crop is produced without irrigation. It has to depend for its germination on the moisture conserved from the previous monsoon and tide over the hot weather with that moisture till the monsoon breaks. As the cane grows mainly during the monsoon period of 3 months, the growth consequently depends upon the vagaries of the rainfall, a late monsoon particularly depressing the yield. Floods often result from excessive precipitation in the sub-montane area and a poor crop follows. The area north of the river is entirely a white sugar tract possessing over three fifths of the total area under cane in the State and also 25 out of a total of 29 factories.

It will be clear from the foregoing paragraphs that the sugarcane crop in the State is raised under widely varying conditions of soil and climate, as represented by the different zones. In order to render real and effective service to the cultivating community in the shape of definite and dependable advice as regards variety to plant, kind and quantity of manure to add, the most profitable schedule of irrigation to follow and some other aspects, it is therefore of the utmost importance to carry out extensive experiments on cultivators' fields widely scattered over the State. The need for this has been widely appreciated in recent years (Yates, Finney and Panse, 1952), the inadequacy of results obtained in a few experimental farms as a sound basis for advising cultivators having been strongly felt in this connection. These farms can hardly be taken as representative of the soil conditions obtaining in innumerable cultivators' fields in a particular tract. Further, they have attained a definitely higher level of fertility as a result of years of sound manuring and management in contrast to the exhausted condition of soils in cultivators' field which have been drained of their nutrient reserves with hardly any replenishment afforded over ages. Crop responses under the two divergent sets of conditions are therefore bound to differ very widely. Under the reorganised Cane Development Scheme in Bihar, a beginning was made in this direction, the ultimate objective being not only confined to a study of the yield responses to the various treatments envisaged but also extending to observations on such other aspects as quality attributes of cane and incidence of pests and diseases in relation to such treatments.

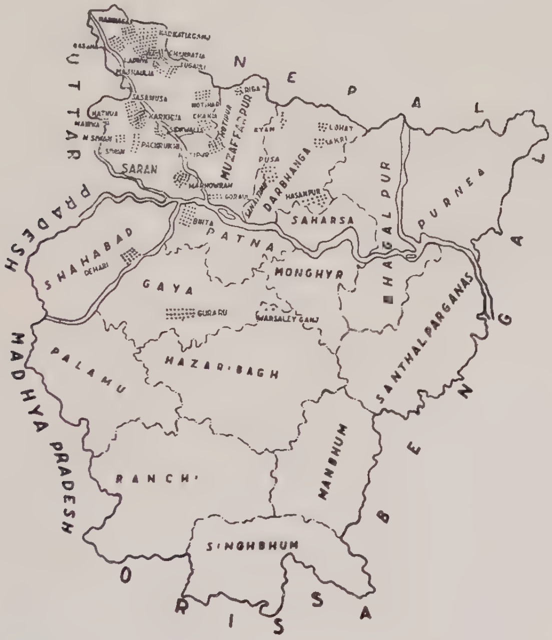
The work reported here relates to manurial experiments of this nature carried out over a period of five years. The experiments were laid out on cultivators' fields scattered over the entire sugar belt and aimed at assessing responses to manurial schedules found most effective at the Research Station and in a large number of co-ordinated experimental centres attached thereto. In Bihar, similar experiments on crops other than sugarcane have been reported by Mukherjee (1952).

METHODS AND MATERIALS

The experiments were laid out on cultivators' plots scattered extensively over all parts of the sugar belt, representing the widely divergent conditions obtained (Plate IV). The scheme of experimentation was identical in the first four years (1950-51 to 1953-54) but differed materially in the fifth year (1954-55). The two schemes are described separately.

PLATE IV

SCATTER OF MANURIAL EXPERIMENTS
IN CULTIVATORS PLOTS


NEPAL
UTTAR PRADESH
MADHYA PRADESH
ORISSA
BENGAL
SARAN
MUZAFFARPUR
DARBHANGA
SAHARSA
BHAGALPUR
PURNEA
PATNA
SHAHABAD
GAYA
MONGHYR
SANTHAL PARGANAS
PALAMU
HAZARIBAGH
RANCHI
MANBHUM
SINGHBHUM
NARKATIAGANJ
CHANPATIA
SUGAULI
LAURIYA
MAJHAULIA
SASAMUSA
HATHUA
KARKHIA
MOTIHARI
CHAKIA
SIDHWALIA
PACHRUKHI
SIWAN
RIGA
RYAM
LOHAT
SAKRI
PUSA
MARHOWRAH
GORAUL
HASANPUR
BIHTA
DEHARI
GURARU
WARSALIGANJ

(1) Years 1950-51 to 1953-54 :

The lay out was a simple one, a plot of an acre in size being divided into three equal portions and the three treatments applied in the three portions of the plot. The treatments were :—

(i) D_0—No manure (control)

(ii) D_1—A lower dose of manure, being $40N+50\ P_2O_5$ in North Bihar and $60N+50\ P_2O_5$ in South Bihar

(iii) D_2—A higher dose of manure, being $60N+75\ P_2O_5$ in North Bihar and $80N+60\ P_2O_5$ in South Bihar

During 1950-51 and 1952-53, two series of experiments were conducted :

(i) Organic series (Oil cake+single superphosphate, a small quantity of ammonium sulphate being added to get the required NP levels).

(ii) Inorganic series (Ammonium sulphate + single superphosphate).

In 1951-52, two series of inorganic fertilisers were under examination, viz.,

(i) Ammophos and (ii) Ammonium sulphate + single superphosphate.

In the year 1953-54, only one series was involved, viz., a "mixed series" wherein N was applied half in inorganic and half in organic form as a mixture of Ammonium sulphate and oilcake, the balance of P_2O_5 (over that provided by oilcake) being added as single superphosphate. The total numbers of experiments in the four successive years were 418, 790, 523 and 240 respectively.

(2) Year 1954-55 :

In this year, the survey method of experimentation (Panse and Sukhatme, 1953) was adopted. Two series were involved, viz., Series I which consisted of NP trials laid out in areas which had shown no response to potash and Series II, consisting of N P K trials laid out in areas where responses to potash had been indicated in trials at coordinated experimental centres (confined to the Sub-Himalayan regions of north west Champaran where high rainfall had brought about heavy leaching of bases). The total numbers of experiments in the two series were 445 and 23 and they comprised 8 groups with 4 treatments and 4 groups with 6 treatments respectively. A one acre plot was divided into 4 equal portions in Series I to 6 equal portions in Series II, each portion receiving one of the treatments which were as follows:—

SERIES I

(1)	0	N_1P_1	N_1P_2	N_2P_2	(5)	0	N_1P_1	N_1P_2	N_2P_1
(2)	0	N_1P_1	N_2P_1	N_2P_2	(6)	0	N_1	P_1	N_1P_1
(3)	0	N_1	N_1P_1	N_1P_2	(7)	0	N_1P_2	N_2P_1	N_2P_2
(4)	0	P_1	N_1P_1	N_2P_1	(8)	0	N_2	P_2	N_2P_2

SERIES II

(1)	0	N_1P_1	$N_1P_1K_1$	$N_1P_1K_2$	$N_1P_2K_1$	$N_1P_2K_2$
(2)	0	N_1P_1	$N_1P_1K_1$	$N_1P_1K_2$	$N_2P_1K_1$	$N_2P_1K_2$
(3)	0	N_1P_2	$N_1P_2K_1$	$N_1P_2K_2$	$N_2P_2K_1$	$N_2P_2K_2$
(4)	0	N_2P_1	$N_2P_1K_1$	$N_2P_1K_2$	$N_2P_2K_1$	$N_2P_2K_2$

These designs were prepared in consultation with Dr. Finney, F.A.O. Statistician. The doses of NPK were as follows :

North Bihar

N_1 : 40N
N_2 : 80N
P_1 : 50 P_2O_5
P_2 : 100P_2O_5
K_1 : 80K_2O
K_2 : 160K_2O

South Bihar

N_1 : 60N
N_2 : 120N
P_1 : 30P_2O_5
P_2 : 60P_2O_5

Nitrogen was applied as a mixture of oilcake and ammonium sulphate, two-thirds and one-third of the nutrient being provided respectively in organic and inorganic forms. Phosphate was applied in the form of single superphosphate and potash as muriate of potash. It may be added here that an application of potash had indicated no response except in combination with nitrogen and phosphate, a treatment involving potash alone was not included in the experiments.

The rainfall factor which dominates production almost entirely in North Bihar, varied considerably during the five years (Table I).

TABLE I

DISTRIBUTION OF RAINFALL (IN INCHES) DURING THE FIVE YEARS OF EXPERIMENTATION

Years	1950-51		1951-52		1952-53		1953-54		1954-55	
District	Total	June-Sept.	Total	June-Sept.	Total	June-Sept.	Total	June-Sept.	Total	June-Sept.
Champaran	45.56	39.11	48.65	46.70	57.94	50.64	62.12	57.60	55.27	47.07
Saran	40.64	36.75	28.75	25.87	43.43	40.13	71.06	67.56	32.40	29.48
Muzaffarpur	34.52	30.86	47.79	46.60	51.16	46.14	64.10	59.29	44.82	39.61
Darbhanga	41.86	37.39	32.93	30.09	48.78	44.02	51.23	44.73	45.25	40.17

PRESENTATION OF DATA

(1) Years 1950-51 to 1953-54 : (a) These experiments were carried out in the years 1950-51 and 1952-53, the total numbers in the two years being 84 and 51 respectively. Analyses of data in respect of each factory area (omitted for brevity) showed significant yield increase due to manuring in almost all cases. As between the two doses, differences in yield were generally non-significant. Results of pooled analyses of data for the different districts have been presented in Table II. It will be seen that yield increases over control as a result of manuring are always significant. The higher dose does better than the lower one in all districts of North Bihar but in South Bihar the latter shows a better performance. However, the extra response due to the higher dose as compared to the lower dose satisfied the criterion of statistical significance only in the year 1950-51 in respect of North Bihar as a whole as also for individual districts other than Saran.

TABLE II

MEAN YIELDS IN TONS PER ACRE IN OILCAKE SERIES

	No. of expts.	D_0	D_1	D_2	L.S.D. at 5%
		1950-51			
Saran	16	24.2	32.7	39.2	7.05
Champaran	7	21.0	23.7	26.3	1.43
Muzaffarpur	17	13.8	17.4	20.1	1.43

TABLE II (Contd.)

	No. of expts.	D_0	D_1	D_2	L.S.D. at 5%
			1950-51		
Darbhanga	35	13.2	19.0	21.5	1.55
North Bihar	75	16.4	22.0	25.4	2.68
South Bihar	9	18.7	22.5	20.7	1.91
			1952-53		
Saran	23	22.5	24.5	25.0	1.80
Champaran	26	17.6	21.8	22.1	1.36
Darbhanga	2	10.8	15.3	19.4	—
North Bihar	51	19.5	22.8	23.3	1.58

(b) Ammophos series : These experiments, 215 in number, were carried out during 1951-52. Here also, yield responses to manuring were significant in almost all cases. An examination of Table III depicting results of pooled analyses will show that responses to manuring are always significant. As between the two doses, systematically higher yields are afforded by the higher dose although the differences are significant only in respect of Saran, Muzaffarpur and North Bihar as a whole. On the contrary, the lower dose does better in South Bihar, the contraction against the higher dose being however non-significant.

TABLE III

MEAN YIELDS IN TONS PER ACRE IN AMMOPHOS SERIES
1951-52

	No. of expts.	D_0	D_1	D_2	L.S.D. at 5%
Saran	72	18.6	24.2	27.4	1.40
Champaran	54	18.3	24.7	25.1	1.76
Muzaffarpur	21	16.0	22.7	28.7	3.16
Darbhanga	63	15.4	20.1	20.8	1.11
North Bihar	201	17.3	22.9	25.0	1.58
South Bihar	103	20.4	28.1	27.6	0.70

(c) Ammonium sulphate series : These experiments were conducted during 1950-51, 1951-52 and 1952-53, the numbers being 241, 324 and 422 respectively. As in the other series yield increases due to manuring were significant in almost all cases. The results of pooled analyses (Table IV) would show that responses to manuring were always significant. During 1950-51, the higher dose did uniformly better than the lower dose in North Bihar but the reverse held good for South Bihar. The differences were however significant only in so far as Saran and Muzaffarpur were concerned. In 1951-52, the higher dose did better in all areas other than the district of Saran where the reverse held good. The differences were, however, significant in respect of Muzaffarpur district only. Similarly during the year 1952-53 higher yields were obtained in all areas except Champaran district where the lower dose did significantly better. However, the better performance under higher dose fell short of the level of significance in South Bihar.

TABLE IV

MEAN YIELDS IN TONS PER ACRE IN AMMONIUM SULPHATE SERIES

	No. of expts.	D_0	D_1	D_2	L.S D. at 5%
			1950-51		
Saran	58	17.7	23.7	25.9	1.76
Champaran	52	16.6	20.7	21.8	1.10
Muzaffarpur	27	15.6	20.0	23.3	1.88
Darbhanga	48	16.3	22.9	23.6	1.76
North Bihar	185	16.7	22.1	23.8	1.58
South Bihar	56	18.9	23.9	22.1	2.65
			1951-52		
Saran	189	18.6	27.1	26.6	1.36
Champaran	74	12.9	18.1	18.5	0.85
Muzaffarpur	39	14.4	20.3	25.8	1.51
Darbhanga	22	11.9	16.0	16.8	1.76
North Bihar	324	16.4	23.5	24.0	1.29
			1952-53		
Saran	111	19.9	24.8	26.3	1.36
Champaran	196	21.7	27.9	26.9	0.63
Muzaffarpur	47	17.4	22.9	28.2	1.47
Darbhanga	49	17.2	21.8	26.3	0.77
North Bihar	403	20.1	25.7	26.8	0.96
South Bihar	19	25.0	32.8	34.3	2.32

(d) **Mixed series :** This series was laid out in 1953-54, the total number of experiments being 240. It will be seen from Table V, depicting pooled analyses of data, that both levels of manuring produced significant increases in yield over control. The higher dose did better than the lower one in Saran district as also in South Bihar but the difference was non-significant in the former case. In other districts, the performance of the lower dose was somewhat better, although not significantly so.

TABLE V

MEAN YIELDS IN TONS PER ACRE IN MIXED SERIES
1953-54

	No. of expts.	D_0	D_1	D_2	L.S.D. at 5%
Saran	43	15.6	21.4	23.4	3.8
Champaran	51	17.8	23.1	22.9	3.6
Muzaffarpur	19	14.9	24.3	22.2	3.7
Darbhanga	25	13.8	19.5	19.4	1.6
North Bihar	138	16.0	22.1	23.3	1.0
South Bihar	12	21.6	25.9	28.9	2.4

A comparative idea of responses under the four series in the different districts and soil divisions of the State can be had from Table VI and of the economics involved from Table VII and Plate V.

TABLE VI

AVERAGE YIELD INCREASES (TONS/ACRE) OVER NO MANURE PLOTS IN DIFFERENT SERIES (1950-51 TO 1953-54)

Series/District or Soil divison	Ammon sulph + Single super	Ammophos	Oilcake + Single super	Ammon sulph +Oil-cake +Single super
(i) District				
		(a) Lower dose (D_1)		
Saran	6.5	5.8	7.1	5.9
Champaran	6.2	6.3	3.1	5.3
Muzaffarpur	5.2	6.7	3.5	9.4
Darbhanga	5.1	4.7	5.1	5.8
South Bihar	4.2	7.8	3.7	4.3
		(b) Higher dose (D_2)		
Saran	7.5	8.8	8.8	7.8
Champaran	5.3	6.8	4.9	5.1
Muzaffarpur	9.9	12.7	6.3	7.3
Darbhanga	7.1	5.4	6.6	5.7
South Bihar	5.3	7.2	2.0	7.3
(ii) Soil division				
		(a) Lower dose (D_1)		
Calcareous	6.1	5.5	4.7	6.1
Non-calcareous	6.2	5.9	4.3	5.7
Sone alluvium	6.5	9.1	5.2	4.7
Heavy clay	2.7	1.6	1.9	2.3
		(b) Higher dose (D_2)		
Calcareous	7.5	8.4	7.3	6.8
Non-calcareous	5.5	4.8	5.3	4.8
Sone alluvium	5.2	8.1	2.4	7.7
Heavy clay	3.3	3.2	1.4	5.0

TABLE VII

NET PROFITS IN RUPEES PER ACRE DUE TO MANURING IN DIFFERENT DISTRICTS AND SOIL DIVISIONS

(1950-51 to 1953-54)

Series/District or Soil division	Ammon sulph +Single super			Ammophos			Oilcake + Single super			Ammon sulph +oil cake +Single super		
	D_1	D_2	Mean	D_1	D_2	Mean	D_1	D_2	Mean	D_1	D_2	Mean
(i) District												
Saran	172	176	174	165	263	214	175	193	184	146	182	164
Champaran	124	94	109	194	187	190	40	51	46	124	79	102
Muzaffarpur	127	268	198	206	411	309	42	100	71	277	164	221
Darbhanga	121	160	141	132	135	134	102	112	107	142	101	122
South Bihar	88	96	92	248	204	226	50	Uneconomic		87	163	127

TABLE VII (Contd.)

Series/District or Soil division	Ammon sulph +Single super			Ammophos			Oilcake+Single super			Ammon sulph + oil cake +single super		
	D_1	D_2	Mean	D_1	D_2	Mean	D_1	D_2	Mean	D_1	D_2	Mean
(ii) **Soil division**												
Calcareous	156	176	166	162	248	205	87	137	112	153	145	149
Non-calcareous	160	101	131	179	116	148	71	63	67	141	71	106
Heavy clay	33	19	26	18	40	29	Uneconomic		—	13	76	45
Sone alluvium	173	89	131	298	239	269	104	,,	—	102	177	140

A scrutiny of the figures in respect of the net profits due to manuring under the different series will bring out the outstanding performance of Ammophos in all districts and in each of the soil divisions.

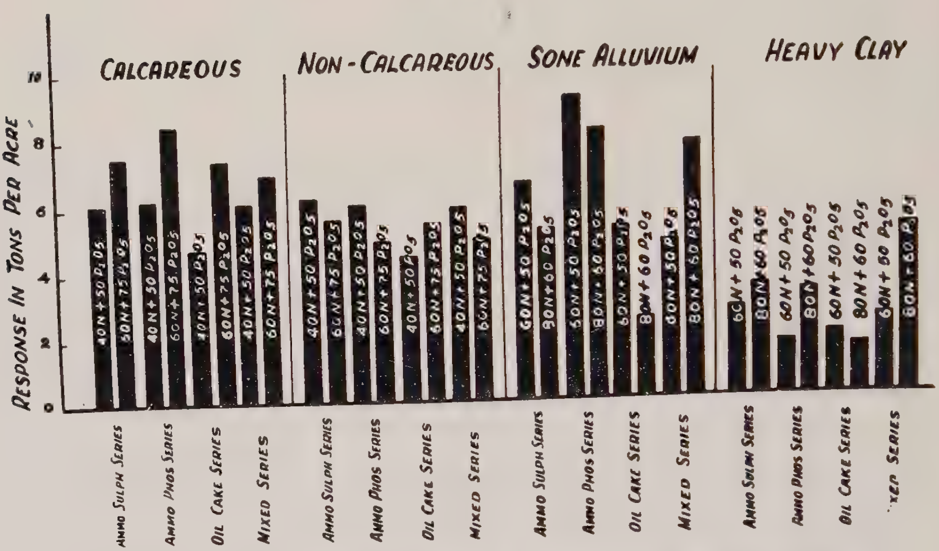
Thus, excepting the district of Darbhanga where it is a close second to Ammonium sulphate, Ammophos affords by far the largest mean profit per acre, ranging from Rs. 309 in Muzaffarpur to Rs. 190 in Champaran. Similarly, with the exception of heavy clay soil division where profits were generally low (the highest gain of Rs. 45 per acre being obtained in the "mixed" series), Ammophos was always outstanding and gave profits varying from Rs. 248 in calcareous soil (Sone alluvium proving a close second with Rs. 239 per acre) to Rs. 116 in non-calcareous soil. Profits in the oilcake series were generally poor, comparatively satisfactory results being obtained in the districts of Saran (Rs. 184) and Darbhanga (Rs. 107) and in the calcareous soil division (Rs. 112) as also under the lower dose in Sone alluvium soil (Rs. 104). Oilcake manuring in both doses proved uneconomical in heavy clay soil and the same held good in respect of the higher dose in Sone alluvium soil and in South Bihar considered as a whole. Oilcake in combination with Ammonium Sulphate was generally comparable to Ammonium Sulphate used as the sole source of Nitrogen and both these series afforded profits generally lying intermediate between those under Ammophos on the one hand and oilcake manuring on the other.

(2) Year 1954-55.

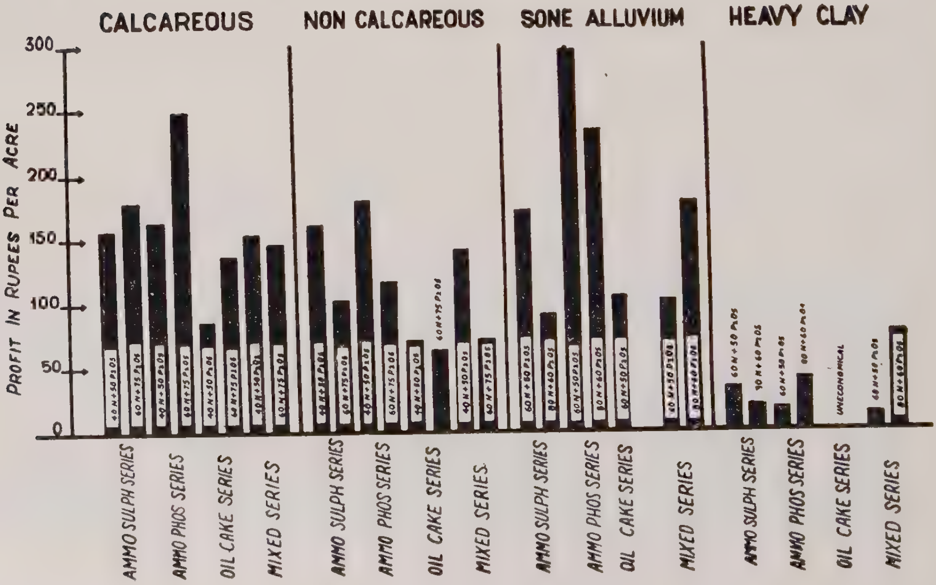
(i) Series I : NP trials:- Pooled averages in respect of yield increments over control (no manure) accruing from different treatments have been worked out with reference to the districts and soil divisions of the State (Table VIII: Plate VI). It will be seen that responses are highest for the N_2P_2 treatment except in Muzaffarpur district where N_2P_1 also shows the same order of performance. The increase in yield ranges from 7.7 tons in Muzaffarpur to 10.8 tons in Champaran so far as North Bihar is concerned while for the South Bihar districts the increases vary between 11.9 tons in Patna and 30.8 tons in Shahabad. Considering responses with reference to the soil divisions, N_2P_2 is uniformly most effective treatment, the increments in yield being 10.3, 9.4, 16.8 and 18.2 tons for the calcareous, non-calcareous, heavy clay and Sone alluvium soils respectively. Combinations of N and P will be seen to produce superior results over single

PLATE V

RESPONSE TO MANURES IN DIFFERENT SOIL DIVISIONS (1950-51 TO 1953-54)



PROFIT DUE TO MANURING IN DIFFERENT SOIL DIVISIONS (1950-51 TO 1953-54)



nutrient applications, the advantage resulting from combination being greater at higher levels of the nutrients. Responses to N and P_2O_5 used alone are considerably high and this effect in respect of P_2O_5 observed on cultivators' fields runs counter to general experience in farm experiments. It may be mentioned in this connection that similar high responses to P_2O_5 applied singly have recently been recorded on cultivator's field in case of wheat and a few other crops in Bihar (P. Sinha : Unpublished work).

TABLE VIII

YIELD RESPONSES TO DIFFERENT TREATMENTS IN (TONS/ACRE) OVER CONTROL (NO MANURE) DURING 1954-55

(i) Districts

Treatment	Champaran	Saran	Muzaffarpur	Darbhanga	North Bihar	Patna	Gaya	Shahabad	South Bihar
N_1	3.2	3.8	2.6	3.8	3.4	9.4	6.5	10.5	8.6
N_2	5.6	4.9	4.1	7.8	5.5	6.0	9.4	—	8.5
P_1	2.4	3.2	5.5	3.6	3.1	5.3	7.9	6.5	6.3
P_2	4.7	5.3	3.9	4.6	4.5	3.3	3.5	—	3.8
N_1P_1	5.2	6.8	5.6	4.5	5.7	7.3	7.6	18.9	10.4
N_1P_2	6.9	6.6	5.5	6.4	6.6	9.5	10.5	21.7	12.4
N_2P_1	7.9	8.2	7.8	7.8	7.3	12.1	14.7	25.0	15.1
N_2P_2	10.8	9.9	7.7	9.3	10.0	11.9	15.5	30.8	17.5

(ii) Soil divisions

	Calcareous	Non-calcareous	Heavy clay	Sone alluvium
N_1	3.6	3.4	6.5	9.9
N_2	6.5	2.2	9.4	6.0
P_1	2.8	3.9	7.2	5.7
P_2	5.4	1.9	3.7	4.0
N_1P_1	5.2	5.4	7.6	12.1
N_1P_2	6.5	6.9	10.5	14.01
N_2P_1	8.1	7.5	13.3	16.4
N_2P_2	10.3	9.4	16.8	18.2

MEAN RESPONSES TO N AND P

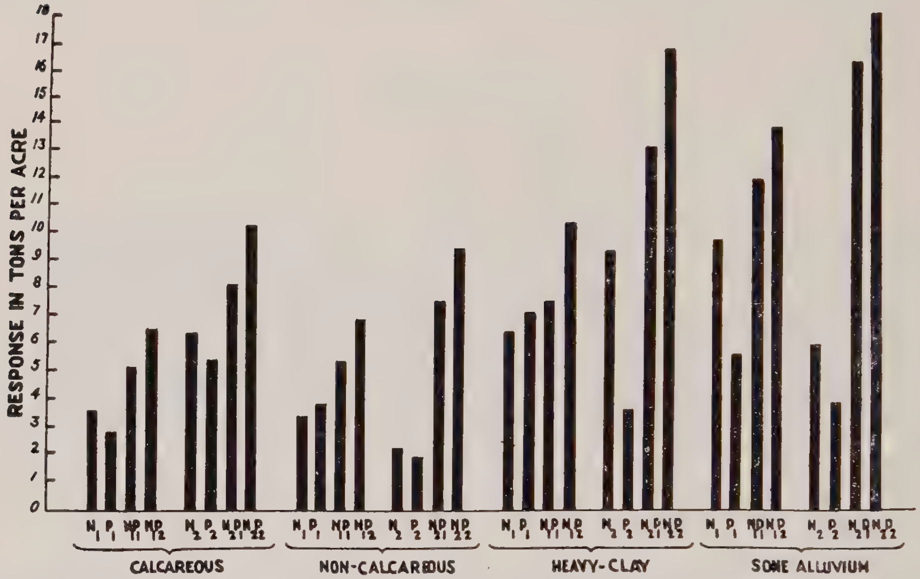
Mean responses to N and P with reference to the different districts and soil divisions have been depicted in Tables IX and X. It will be seen that the responses to N_1 vary from 1.4 tons in Muzaffarpur to 11.4 tons in Shahabad districts, the range with regard to N_2 being 3.4 tons (Muzaffarpur) to 18.5 tons (Shahabad). In North Bihar, the response to N is more or less proportional to the dosage while in South Bihar a diminishing return is apparent from the figures in respect of response to the higher dose. So far as the soil divisions are concerned, responses to N_1 vary from 2.4 tons in calcareous to 8.8 tons in Sone alluvium. those with regard to N_2 ranging from 4.5 tons (non-calcareous) to 10.3 tons (Sone

PLATE VI

RESPONSE TO MANURE IN DIFFERENT SOIL DIVISIONS

(NP SERIES)

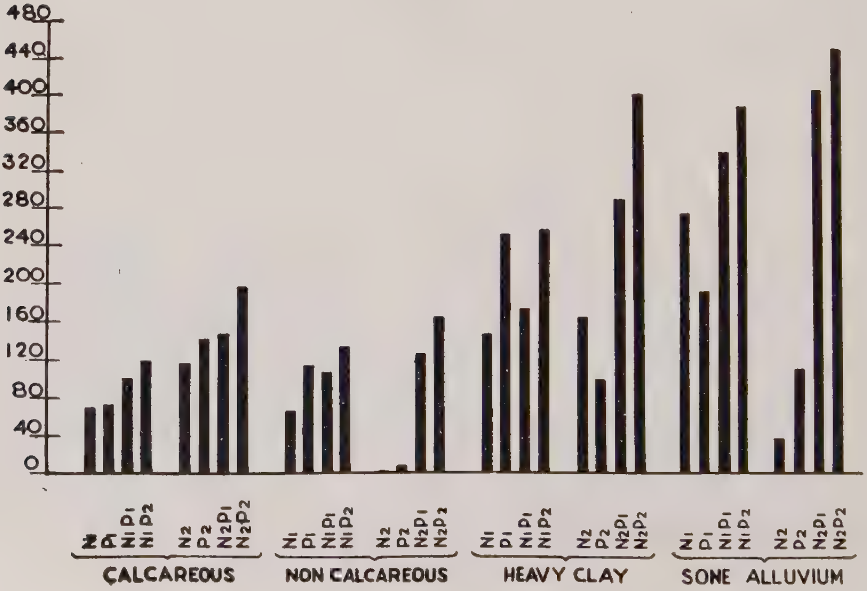
1954-55



PROFIT DUE TO MANURING IN DIFFERENT SOIL DIVISIONS

(NP SERIES)

1954-55



alluvium). It will be noted that the heavy clay division shows quite a high response to N_2 approaching that of Sone alluvium but the performance is much poorer at N_1 level. As between calcareous and non-calcareous soils, the differences are not very pronounced.

Coming to phosphate responses, the best results are again obtained in Shahabad district (7.5 and 11.1tons respectively for P_1 and P_2), Darbhanga showing the lowest order of response (1.7 and 2.9 tons for the two respective levels). The advantages of P_2 over P_1 are also clear in respect of all districts other than Muzaffarpur, Patna and Gaya. Considered with reference to soil divisions, responses to both levels of P are highest in Sone alluvium (6.1 and 6.8 tons), heavy clay soil division coming next (4.1 and 5.0 tons). As between calcareous and non-calcareous soils responses to the higher dose are identical (4.1 tons) but the former shows a clearly lower response (2.0 tons) at the lower level as compared to the higher (3.7 tons). The benefit resulting from a higher level of phosphate application is most pronounced in calcareous soil.

TABLE IX

MEAN RESPONSES TO NITROGEN (TONS/ACRE) DURING 1954-55

	N_1	N_2	Mean
(i) District			
Champaran	2.7	5.6	4.1
Saran	2.9	4.8	3.9
Muzaffarpur	1.4	3.4	2.4
Darbhanga	2.4	5.6	4.0
North Bihar	2.7	5.2	4.0
Patna	5.8	7.1	6.5
Gaya	4.4	9.4	8.8
Shahabad	11.4	18.5	15.0
South Bihar	7.1	10.3	8.9
(ii) Soil division			
Calcareous	2.4	5.6	4.0
Non-calcareous	3.3	4.5	4.0
Heavy clay	4.6	9.6	7.1
Sone alluvium	8.8	10.3	9.6

TABLE X

MEAN RESPONSES TO PHOSPHATE (TONS/ACRE) DURING 1954-55

	P_1	P_2	Mean
(i) **District**			
Champaran	2.1	4.5	3.3
Saran	3.2	4.3	3.8
Muzaffarpur	4.0	3.5	3.8
Darbhanga	1.7	2.9	2.3
North Bihar	2.6	4.0	3.3
Patna	3.1	3.1	3.1
Gaya	4.7	4.5	4.6
Shahabad	7.5	11.1	9.3
South Bihar	4.9	5.5	5.2
(ii) **Soil division**			
Calcareous	2.0	4.1	3.1
Non-calcareous	3.7	4.1	4.0
Heavy clay	4.1	5.0	4.6
Sone alluvium	6.1	6.8	6.4

(b) Series II : NPK trials (N. W. Champaran).—The responses to different treatments in this series have been shown in Table XI. In Table XII, responses to potash have been represented as increments in yield resulting from the two levels of K application over three different levels in respect of NP, viz., N_1P_1,

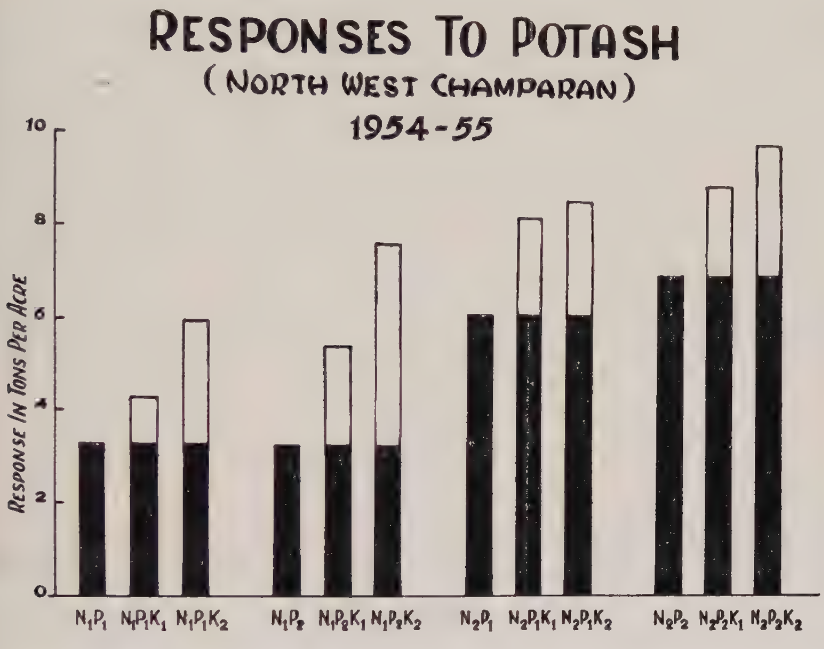
TABLE XI

RESPONSES TO DIFFERENT TREATMENTS IN THE NPK SERIES (TONS/ACRE) DURING 1954-55

Treatment	Increase over control (no manure)	Treatment	Increase over control (no manure)
N_1P_1	3.2	N_2P_1	6.1
$N_1P_1K_1$	4.3	$N_2P_1K_1$	8.2
$N_1P_1K_2$	5.9	$N_2P_1K_2$	8.6
N_1P_2	3.2	$N_2P_2K_1$	9.0
$N_1P_2K_1$	5.4	$N_2P_2K_2$	9.8
$N_1P_2K_2$	7.6		

N_1P_2 and N_2P_1 (Plate VII). It will be seen that for the lower level of K, increments are of the same order for N_1P_2 and N_2P_1 (2.2 and 2.1 tons), being substantially lower under N_1P_1 (1.1 tons). For the higher level of K, on the other hand, response was highest under N_1P_2 (4.5 tons), being of a lower order under N_1P_1 and N_2P_1 (2.8 and 2.5 tons).

PLATE VII



NOTE :- THE UNSHADED PORTIONS REPRESENT INCREASES DUE TO K OVER RESPECTIVE NP LEVELS

TABLE XII

RESPONSES TO POTASH OVER DIFFERENT COMBINATIONS OF N AND P DURING 1954-55

Increments over	Tons/acre	
	K_1	K_2
N_1P_1	1.1	2.8
N_1P_2	2.2	4.5
N_2P_1	2.1	2.5
Mean	1.8	3.2

ECONOMICS OF MANURING FOR DIFFERENT TREATMENTS

Economics of manuring in respect of the treatments under examination calculated after deducting the cost of manures and fertilizers applied from the value of the extra crop harvested, have been shown with reference to the different district and soil divisions in Tables XIII and XIV. It will be seen that N_2P_2 proves most profitable in the districts of Champaran, Saran and Darbhanga in North Bihar and Gaya and Shahabad in South Bihar, yielding net profits per acre to the extent of Rs. 213, Rs. 180, Rs. 158, Rs. 232 and Rs. 923 respectively. In Muzaffarpur and Patna districts, N_2P_1 is most advantageous, giving profits of Rs. 134 and Rs. 246 respectively. This dose is also a close second for the district of Gaya. So far as the soil divisions are concerned N_2P_2 is most profitable in all cases. The extra profit obtained under this dose over N_2P_1 is most pronounced in heavy clay soil. The profits obtained in Sone alluvium are remarkable under all treatments involved.

Additional profits accruing from the two levels of potash application in N.W. Champaran have been shown in Table XV (Plate VIII). It would appear that K_2 in conjunction with N_1P_2 leads to the highest extra profit (Rs. 117 per acre), the least additional benefit being obtained with K_1 in association with N_1P_1 (Rs. 17).

PLATE VIII

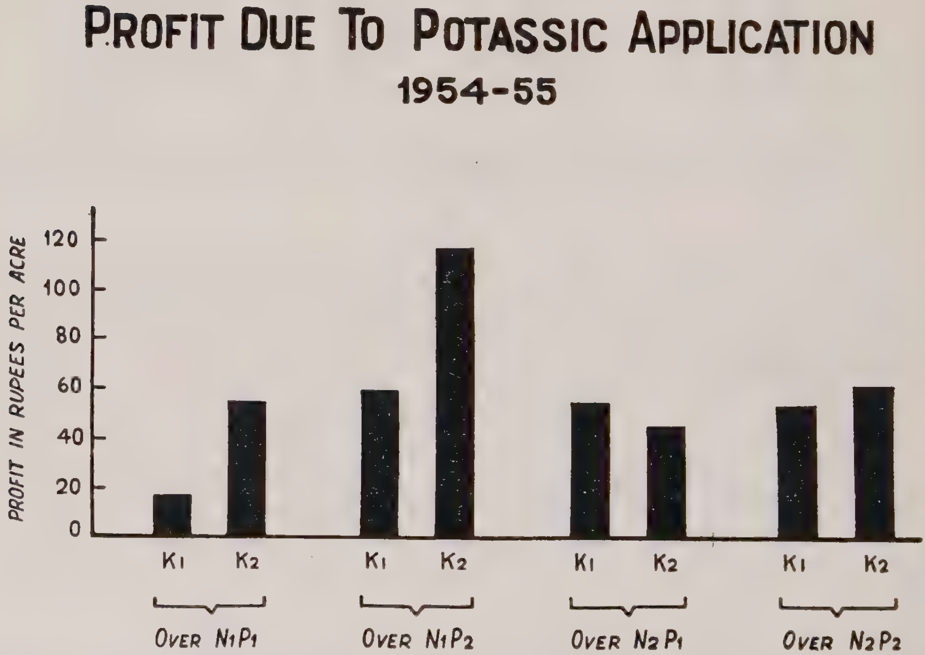


TABLE XIII

PROFITS DUE TO MANURING IN DIFFERENT DISTRICTS IN RUPEES PER ACRE

1954-55

Districts	N_1P_1	N_1P_2	N_2P_1	N_2P_2
Champaran	99	130	123	213
Saran	158	119	147	180
Muzaffarpur	113	78	134	99
Darbhanga	103	114	135	158
North Bihar	120	119	134	183
Patna	158	221	246	216
Gaya	172	258	341	352
Shahabad	591	675	728	923
South Bihar	277	331	356	425

TABLE XIV

PROFITS DUE TO MANURING IN DIFFERENT SOIL DIVISIONS IN RUPEES PER ACRE

(1954-55)

Soil divison	N_1P_1	N_1P_2	N_2P_1	N_2P_2
Calcareous	99	118	146	196
Non-calcareous	107	132	124	163
Heavy clay	172	258	290	402
Sone alluvium	340	389	407	451

TABLE XV

PROFITS IN RUPEES PER ACRE DUE TO POTASSIC APPLICATION

(1954-55)

Increase in profit over	K_1	K_2
N_1P_1	17	55
N_1P_2	59	117
N_2P_1	54	46
Mean	43	73

TABLE XVI

RESPONSES AND NET PROFITS ACCRUING FROM A STANDARD DRESSING OF 20 lbs. N+25 lbs. P_2O_5 PER ACRE

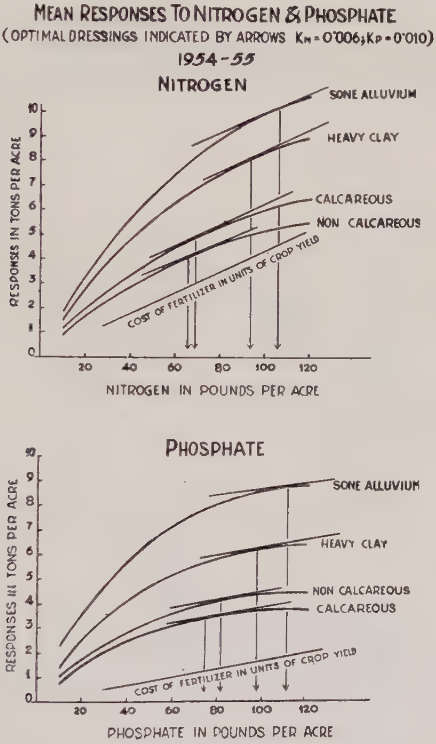
(1954-55)

District or Soil division.	Response (tons/acre)	Net profit (Rupees/acre)
(i) **District**		
Saran	4.5	128
Champaran	4.5	128
Muzaffarpur	3.7	98
Darbhanga	3.5	89
North Bihar	4.1	110
Patna	4.7	135
Gaya	6.8	213
Shahabad	13.9	478
South Bihar	7.4	237
(ii) **Soil division**		
Non-calcareous	4.7	134
Calcareous	4.2	117
Heavy clay	5.3	157
Sone alluvium	7.7	246

STANDARDISED RESPONSE AND PROFITS : OPTIMAL DRESSING OF N AND P

As the nutrient levels under consideration differed in North and South Bihar, responses were standardised to a level of 20 N+25 P_2O_5 in order to obtain a comparative idea of the performances in different districts and soil divisions. For this purpose, Mitscherlich exponential response curves, as used by Growther and Yates (1941) and Carey and Robinson (1953) were drawn, the values for the constant K (which determines the curvature) being taken from Carey and Robinson's paper (loc. cit.), viz., $K_n=0.006$ and $K_p=0.010$. The response curves (Plate IX) were utilised in working out the optimal dressings in respect of N and P_2O_5. Optimal combinational dressings of the two nutrients were also calculated. The responses and profits accruing from a standard dressing of 20 N+25 P_2O_5 have been shown with reference to the districts and soil divisions in Table XVI (Plate X). It would appear that among the districts of North Bihar responses are highest in Saran and Champaran (4.5 tons), Muzaffarpur and Darbhanga showing responses of a lower order (3.7 and 3.5 tons). Net profits show the same trend, being Rs. 128 in Saran and Champaran as against Rs. 98 and Rs. 89 for Muzaffarpur and Darbhanga. So far as South Bihar is concerned, Shahabad leads with a response of 13.9 tons and profits of Rs. 478 per acre, followed by Gaya (6.8 tons and Rs. 213) and Patna (4.7 tons and Rs. 135). The responses obtained and profits recovered are outstanding for South Bihar in general and Shahabad district in particular. Considering the soil divisions, Sone alluvium proves most responsive to manuring (7.7 tons with a net profit of Rs. 246 per acre) followed in order by heavy clay (5.3 tons and Rs. 157), non-calcareous soil (4.7 tons and Rs. 134) and calcareous soil (4.2 tons and Rs. 117)

PLATE IX



The optimal dressings of N and P_2O_5 (both separately and in combination) work out as follows for the different soil divisions.

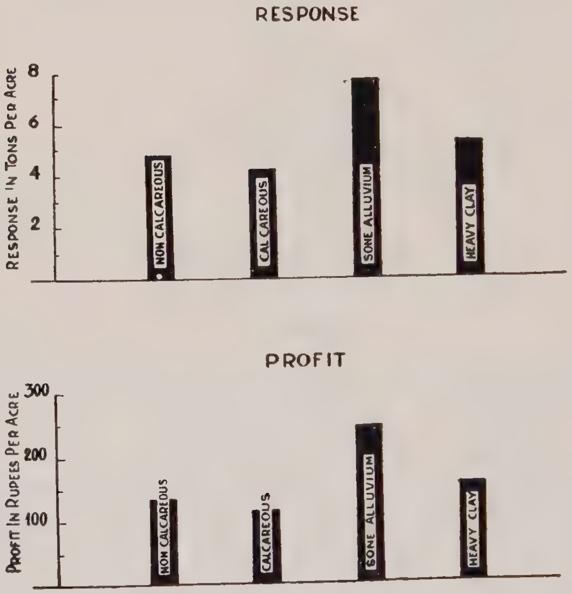
Soil divison	Optimal N (lbs./acre)	Optimal P_2O_5 (lbs /acre)	Optimal $N+P_2O_5$ (lbs./acre)
Non-calcareous	58.2	81.9	59.2N + 97.5 P_2O_5
Calcareous	69.3	75.3	51.9N + 93.1 P_2O_5
Heavy clay	93.7	97.5	68.0N + 102.8 P_2O_5
Sone alluvium	106.0	111.2	94.7N + 118.9 P_2O_5

DISCUSSION

These studies bring out in bold relief the high responses accruing in cultivators' fields as a result of manure and fertilizer application and leaves no doubt as to the supreme importance of manuring vis-a-vis realisation of objects in respect of crop yields. It will be realised, therefore, that any efforts towards formulation of the right manurial schedule for each sugarcane growing area are bound to result in information of vital importance to the industry. As the soil survey scheme of factory areas progresses, the need to determine immediately the kind and quantity of manures and fertilizers in different soil types isolated also becomes urgent. The completion of factory area tube-well scheme and of other similar projects also envisages rapid development of cane in concentrated blocks round such irrigation points and there is evident need to determine under cultivators' conditions variations in irrigation and manuring schedules worked out at the different research stations. For this purpose, a large number of experiments need to be laid out on cultivators' fields every year and besides yield responses, various other aspects being gradually incorporated, such as collection of profile soil samples from each experimental plot with a view to correlating crop responses to soil characters ; study of the interaction of irrigation and manuring at different levels; juice quality variations in relation to treatments; residual effects on succeeding grain crops; pest and disease incidence at harvest with reference to treatments applied and so on. There is little doubt that such an endeavour will go a long way towards placing the Industry on a sound footing.

PLATE X

STANDARD RESPONSES TO NITROGEN & PHOSPHATE & PROFIT PER ACRE
STANDARD DRESSING 20N+25 P_2O_5 ACRE (K_N=0·006, K_P=0·010)



SUMMARY

1. The results of manurial experiments on sugarcane conducted on cultivators' fields widely scattered over the entire sugar belt of Bihar have been reported in the paper.

2. The experiments conducted during the first four years comprised four separate series, viz., (*i*) Ammophos (*ii*) Ammonium sulphate with single superphosphate (*iii*) oilcake with single superphosphate and (*iv*) oilcake and ammonium sulphate with single superphosphate, a higher and a lower level of manuring being examined against no manure as control. In North Bihar, the manurial levels were $40N+50\ P_2O_5$ and $60\ N+75P_2O_5$, those for South Bihar being $60N+50P_2O_5$ and $80\ N+60P_2O_5$.

3. In the fifth year, the survey method of experimentation was adopted. Two series were involved, viz., (*i*) N P trials in areas showing no response to K which consisted of 8 groups with 4 treatments (single and combinational doses of N_1, N_2, P_1, P_2 against no manure as control) and (*ii*) NPK trials in the high rainfall areas of N. W. Champaran where potash response had been observed, this series comprising 4 groups with 6 treatments (single doses of N_1, N_2, P_1, P_2 and combinational doses of N_1, N_2, P_1, P_2, K_1, K_2 against no manure as control). N_1, N_2, P_1, P_2, K_1, K_2 stood for 40N, 80N, $50P_2O_5$, 100 P_2O_5, 80 K_2O, 160 K_2O in North Bihar while in South Bihar N_1, N_2 represented 60 N and 120 N, P_1, P_2 stood for 30 P_2O_5 and 60 P_2O_5, no potash treatments being examined in this region. In all cases, the combination was one of ammonium sulphate and oilcake (contributing respectively one-third and two-thirds of the Nitrogen) with single superphosphate.

4. In practically all trials, significant yield responses to manuring were obtained. In the first four yearsof experimentation the higher dose on an average, gave a higher outturn per acre in North Bihar as compared to the lower dose but the differences were generally non-significant. In South Bihar, on the other hand, the reverse trend was indicated. In the fifth year, however, high doses of manuring proved very effective in increasing acre-yields, a dosage of 80 N : 100 P_2O_5 doing best in North Bihar with the 120 N : 60 P_2O_5 combination excelling in South Bihar. So far as the NPK trials in N.W. Champaran were concerned, marked responses to potash application were recorded, the effect being most pronounced with 160 lbs. K_2O over a combination of 40 lbs. N and 100 lbs. P_2O_5.

5. In the trials of the first four years, Ammophos generally gave the highest profits and oilcakes the least. Oilcake manuring proved hardly profitable in South Bihar. Oilcake in combination with Ammonium sulphate was generally comparable to the latter used as the sole source of Nitrogen.

6. Individual effects of N and P_2O_5 calculated with reference to the fifth year's data show that the responses to N and P_2O_5 at both levels are highest in Sone alluvium. In the calcareous soil division, the advantage resulting from a higher level of P_2O_5 (as compared to the lower level) is also most pronounced.

7. The fifth year's data show high profits from manuring, the figures varying between Rs. 99 per acre in calcareous soil under 40 N : 50 P_2O_5 dose to Rs. 451 per acre in Sone alluvium resulting from a 120 N: 60 P_2O_5 dose. Likewise, profits due to potash application in N. W. Champaran vary from Rs. 17 per acre (80 lbs. K_2O over 40 lbs. N and 50 lbs. P_2O_5), to Rs. 117 per acre (160 lbs. K_2O over 40 lbs. N and 100 lbs. P_2O_5).

8. On the basis of the fifth year's trials, optimal combinational dressings of N and P_2O_5 have been worked out for the different soil divisions.

These are:

Non-calcareous	59.2 N + 97.5 P_2O_5
Calcareous	51.9 N + 93.1 P_2O_5
Heavy clay	68.0 N + 102.8 P_2O_5
Sone alluvium	94.7 N + 118.9 P_2O_5.

ACKNOWLEDGEMENT

The authors are indebted to the Government of Bihar and the Indian Central Sugarcane Committee for jointly financing the Sugarcane Research Scheme in Bihar under which the present work was carried out. Their thanks are also due to Dr. A.S. Chakravarti for going through the manuscript and making useful suggestions. They also wish to place on record their appreciation of the co-operation extended by the sugar factories and the field work done by Cane Development staff in different areas.

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DISCUSSION

Dr. Arakeri asked if the soils on which these experiments were being conducted had been analysed. Mr. Khanna replied that the experiment had been scattered over different soil divisions whose characteristics had been fully studied in the soil survey conducted earlier.

The following paper was taken as read in the absence of the authors.

Paper

FILTER-PRESS CAKE AS A FERTILIZER

George Samuels and Pablo Landrau Jr.

Agricultural Experiment Station, University of Puerto Rico

INTRODUCTION

Every year the sugarcane mills of Puerto Rico produce large quantities of a byproduct called filter-press cake or filter-press mud. An average of 60 pounds of filter-press cake is produced for every ton of sugarcane milled. Assuming an output of 12,000,000 tons of millable cane per year, Puerto Rico has an annual production of about 360,000 tons of filter-press cake to utilize. This dark-brown to black organic material is usually dumped on or near the premises of the factory where it accumulates in piles covering many acres. It is often used in fertilizing nearby sugarcane fields. The rates used are very high and applications up to 100 tons per acre are not rare.

Some filter-press cake has been used by home gardeners as a topdressing for lawns and gardens. The material has also found use in vegetable plantings and on pineapple plantations. However, no specific rate or method of application has so far governed its general use in farm practice.

Very limited information is available in the literature concerning the use of filter-press cake in agriculture. Aside from work by Ramirez (5), Riollano (6), and Hernandez-Medina *et al* (1, 3), most of the reports that have appeared deal mainly with observed results rather than experimental proof.

Beginning in 1949, fertilizer experiments were carried out by the authors on some of the leading economic agricultural crops of Puerto Rico in which results of the use of filter-press cake were compared with those obtained with inorganic commercial fertilizers. It is the object of this paper to report the results of these various experiments in which filter-press cake was used as a fertilizer material. The value of this material as a fertilizer are discussed and practical recommendations are made as to its use.

PHYSICAL AND CHEMICAL PROPERTIES OF FILTER-PRESS CAKE

Filter-press cake consists principally of a mixture of sugarcane fibres, sucrose, coagulated colloids including cane wax, albuminoids and phosphates of lime plus sand and soil. Most of the constituents come from the ground-up sugarcane. The lime is added in the process of neutralizing and clarifying the cane juice, and the sand and soil enter as foreign matter clinging to the cane.

Physically, filter-press cake is a soft, spongy, light weight amorphous dark-brown to black material. It can readily absorb large quantities of moisture when dry. It generally contains from 55 to 70 percent of moisture on a wet basis when taken fresh from the factory. When allowed to air-dry the moisture content averages about 15 percent. Its volume-weight is very low, being only 0.375 on a dry-weight basis, and about 0.57 at 65-percent moisture. Thus 1 ton of filter-press cake at 65-percent moisture (wet basis) would occupy about 56 cubic feet, or approximately 2 cubic yards.

Filter-press cake varies somewhat in chemical composition, depending upon such factors as the cane varieties being ground, the area where cane is grown, the climate, and mill performance. The range and mean values for the various chemical constituents of filter-press cake are given in Table I. These values represent many samples of filter-press cake taken from sugarcane mills from all of the cane-growing areas of Puerto Rico.

TABLE I

THE CHEMICAL COMPOSITION AND PHYSICAL PROPERTIES OF FILTER-PRESS CAKE[1]

Constituent	Samples Number	Composition on a dry-weight basis	
		Average percent	Range of values percent
Nitrogen (N)	43	2.19	1.07-3.13
Phosphorus (P_2O_5)	43	2.77	1.34-6.30
Potassium (K_2O)	41	0.44	0.02-1.77
Calcium (CaO)	42	3.05	0.98-6.24
Magnesium (MgO)	2	0.49	0.42-0.58
Manganese (MnO_2)	6	0.17	0.10-0.24
Iron (Fe_2O_3)	6	1.05	0.26-4.71
Boron (B_2O_3)	4	0.01	0-0.02
Organic Matter	1	39.5	—
Loss in ignition	1	45.2	—
Sucrose	4	3.0	2-4
Moisture[2] (fresh)[3]	18	61.0	56-69
Moisture[2] (stored)[4]	23	15.0	9-47
Volume-weight[5]	2	0.375	0.372-0.378

Of the major plant nutrients (N-P-K), filter-press cake is highest in phosphorus as P_2O_5, nitrogen being generally a bit lower. The average values are 2.19 percent for N and 2.77 percent for P_2O_5, with fluctuations between 1.07 to 3.13 percent for N and between 1.34 to 6.30 percent for P_2O_5. The nitrogen occurs

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1. Based on the analysis of samples taken by the authors, plus some given in literature (3, 5, 6).
2. Calculated on a wet basis.
3. Fresh material taken from the Oliver and press filters at the mill.
4. Material taken from the dump piles near the mills where it had been exposed to the weather.
5. Calculated on a dry-weight basis and expressed in cubic centimeter per gram.

mainly as protein and in other complex forms rather than as the less complex ammonia or nitrate forms. However, conversion to these simpler forms proceeds very rapidly as the filter-press cake decomposes. Phosphorus is present in the form of complex organic combinations such as phospholipids and nucleoproteins. Some phosphorus is also present as calcium phosphates which are formed when the lime is added in the process of clarification. Usually most of the phosphorus is present in organic complexes which decompose readily to supply considerable available phosphorus for plant use.

The potassium content of filter-press cake is low. It averages 0.44 percent as K_2O with a range from 0.02 to 1.77 percent—the higher figure being extremely rare. In as much as potassium is not known to be fixed in the cane plant in any complex organic form, that present is extracted in the juice and by the water added in the milling process, and most of it is found in the molasses. The ash of molasses contains about 32 percent of K_2O_5. The small quantity of potash present in the filter-press cake is in a soluble, very-easily-leached form.

The calcium content of filter-press cake is high and averages about 3 percent as CaO. Most of the calcium is derived from the lime added when processing the sugarcane rather than from the plant itself.

Minor elements such as magnesium, manganese, iron and boron are present in the filter-press cake in fair amounts—enough to be considered as a good source of minor elements for use by the plants. The iron content of filter-press cake averages about 1 percent. All of this iron may not be in a readily available form, as some is found in the soil which forms part of the foreign matter and part occurs as traces of metallic iron derived from the machinery used in the grinding of the cane.

EXPERIMENTAL RESULTS

In the experiments with filter-press cake as a fertilizer, such crops as sugarcane, vegetables, tobacco, and root crops were utilized. The results obtained are reported under the individual crops.

SUGARCANE

The bulk of the filter-press cake used as fertilizer was applied to sugarcane. The results obtained from this material were not outstanding. As can be seen in Table II, cane yields were not appreciably increased where filter-press cake was used. It is to be remembered, however, that commercial fertilizer was used along with the filter-press cake in most of the experiments. It therefore seems wasteful to apply any appreciable quantity of filter-press cake to a field where commercial fertilizer has just been applied.

It is interesting to note that the filter-press cake not only failed to increase yields on unirrigated Santa Isabel silty clay, but actually decreased them with increasing rates of application of filter-press cake in the absence of inorganic fertilizers (see Table II).

TABLE II

RELATIVE SUGARCANE YIELDS FOR 4 SOILS RECEIVING COMMERCIAL CANE FERTILIZERS AND FILTER-PRESS CAKE

	Fertilizer treatment per acre with Commercial inorganic fertilizers			Filter-press cake[1]	Relative sugarcane yields per acre		
	N lbs.	P_2O_5 lbs.	K_2O lbs.	Tons	Tons of cane percent	Sucrose percent	Available 96° sugar percent
Santa Isabel silty clay (irrigated)[2]	176	16	40	0	100	100	100
	176	16	40	10	84	108	92
Santa Isabel silty clay (unirrigated)[3]	250	0	300	0	100	100	100
	250	0	300	20	94	102	96
	0	0	0	20	97	96	93
	0	0	0	40	93	95	87
	0	0	0	60	82	97	80
Coto clay[4]	250	300	300	0	100	100	100
	250	300	300	10	103	100	104
Lares clay[5]	300	300	300	0	100	100	100
	300	300	300	20	112	101	111
Via silty clay[6]	300	300	300	0	100	100	100
	300	300	300	10	103	99	101

Because large quantities of organic material are returned to the soil by the cane trash (7), much of the beneficial influence of filter-press cake is lost as a soil amendment in controlling soil moisture, aeration and temperature. The filter-press cake is beneficial to soils requiring nitrogen and phosphorus. However, where potash requirements are high, the use of filter-press cake only may not guarantee an adequate supply of potassium for the cane.

VEGETABLE CROPS

Filter-press cake has always found favour among our farmers in growing vegetables. Its widest usage has been for the home garden and small vegetable plots of usually less than 1 acre.

Tomatoes. As shown in Table III, filter-press cake increased the yields of tomatoes. When used alone, 20 tons of filter-press cake gave no significantly

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1. Filter-press cake rates calculated on a wet basis.
2. Plant cane, 1950-52, B. 34104 at Central Cortada, Aguirre.
3. Plant cane and 2 ratoons, 1950-54, P.O.J. 2878 at Lajas Substation.
4. First and second ratoons, 1950-52, P.R. 902 at Colonia Irurena, Isabela.
5. Plant cane and 2 ratoons, 1951-54, P.R. 905 at Corozal Substation.
6. First and second ratoons, 1952-54, P.O.J. 2878 at Colonia Santa Teresa, Humacao.

higher yields than did 10 tons per acre. No significant response in yield was obtained with the use of 10 or 20 tons of filter-press cake in conjunction with commercial fertilizer, as compared with commercial fertilizer alone (Table III, treatments 5 and 6 compared with 4). There was a need for nitrogen (treatment 4 compared with 7) and for phosphorus (treatment 4 compared with 8), but not for potassium (treatment 4 compared with 9).

TABLE III

INFLUENCE OF FILTER-PRESS CAKE AND COMMERCIAL FERTILIZERS ON YIELDS OF TOMATOES AND PEPPERS

Treatment No.	Fertilizer treatments per acre with: Commercial inorganic fertilizers N lbs.	P$_2$O$_5$ lbs.	K$_2$O lbs.	Filter press cake[1] Tons	Yields of produce per acre: Tomatoes[2] Cwt.	Peppers[3] Cwt.
1	0	0	0	0	37.5	33.0
2	0	0	0	10	68.6	57.0
3	100	0	0	20	84.0	52.5
4	100	200	200	0	136.4	48.6
5	100	200	200	10	135.0	86.2
6	100	200	200	20	158.9	77.9
7	0	200	200	0	80.5	60.4
8	200	0	200	0	84.7	30.0
9	200	200	0	0	145.4	62.7
Least significant difference needed between treatments at :						
5-percent level					30.9	22.6
1-percent level					41.1	30.0

It is of interest to note that inorganic fertilizers alone gave greater yields of tomatoes than did filter-press cake only (treatment 4 compared with 2 and 3). Riollano (6), working with tomatoes in the same soil, Coto clay, obtained a significant increase in yield by using 12 tons of filter-press cake, plus 1,000 pounds of 8-10-15 fertilizer.

Peppers. The use of filter-press cake at the rate of 10 tons per acre (Table III, treatment 2 minus treatment 1), increased yields of peppers, but 20 tons did not as compared with 10 tons per acre. The use of 10 tons per acre of filter-press cake in combination with commercial fertilizer also increased yields above those obtained with the commercial fertilizer alone (treatment 5 less treatment 4). No greater yield increases were obtained when 20 tons of filter-press cake were used instead of 10 along with the inorganic fertilizer.

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1. Calculated on a wet basis.
2. Data taken from experiment conducted at the Isabela Substation, 1952-53, on a Coto clay with a Plamar variety of tomato.
3. Data taken from experiment conducted at Aibonito, 1952-53, on a Juncos clay with a Puerto Rico Wonder variety of pepper.

Pigeon Peas. Filter-press cake was applied at the rate of 20 tons per acre to pigeon peas growing on a Coto clay at the Isabela Sub-Station, 1953-54. The results of the harvests for 2 years showed no yield response, nor did yields respond to the use of various inorganic fertilizers containing nitrogen, phosphorus, or potassium. It appears that the pigeon pea was able to obtain sufficient available nutrient supply from the soil without fertilizer applications.

TABLE IV

INFLUENCE OF FILTER-PRESS CAKE ON YIELDS OF TOBACCO[1]

Treatment No.	Fertilizer treatment per acre with: Commercial inorganic fertilizers: N lbs.	P$_2$O$_5$ lbs.	K$_2$O lbs.	Filter press cake[2] Tons	Yield of tobacco per acre: First crop 1951-1952 Cwt.	Second crop 1952-1953 Cwt.	Third crop 1953-54 Cwt.	Mean of 3 crops Cwt.
1	0	100	150	0	6.34	8.26	8.77	7.99
2	100	100	150	0	12.38	10.50	20.60	14.49
3	0	100	150	2.5[3]	9.55	10.52	14.01	11.36
4	50	100	150	1.25[4]	11.57	8.61	17.51	13.20
5	150	0	150	0	10.80	10.29	13.50	10.97
6	150	100	0	0	12.43	10.00	18.33	13.68
7	0	100	150[5]	2.5[3]	—	11.19	15.01	—
8	100	100	150[5]	0	—	—	23.90	—
Least singnificant differences needed between treatments at :								
5-percent level					2.17	1.31	3.29	2.26
1-percent level					2.81	1.71	4.34	2.95

Corn. Mayorbela corn grown at the Lajas Substation on a Santa Isabel clay was fertilized with ammonium sulphate and also with filter-press cake in amounts equivalent to 120 pounds of N per acre. There was 1.0 significant response in yield to either.

Tobacco. Filter-press cake was used as a fertilizer in a tobacco fertilizer experiment at Aibonito on a Juncos clay. The results obtained are given in Table IV. When filter-press cake was applied as a nitrogen source in rates equivalent to the nitrogen applied in the form of ammonium sulphate (treatment 3), there was a significant increase over the no-nitrogen treatment (treatment 1). However, yield increases were significantly higher when ammonium sulphate was used as the nitrogen source (treatment 2 compared with treatment 3). When one-half of the nitrogen was in the form of ammonium sulphate and one-half was

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1. Virginia 12 variety of tobacco grown on a Juncos clay at Aibonito.
2. Calculated on a dry-weight basis.
3. The 2.5 tons of filter-press cake (2 percent N) used was calculated to contain 100 lbs. of N.
4. The 1.25 tons of filter-press cake (2 percent N) used was calculated to contain 50 lbs. of N.
5. Lime was applied at the rate of 2 tons of $CaCO_3$ per acre.

deprived from filter-press cake (treatment 4), the yields were comparable to those obtained when ammonium sulphate only was used.

In as much as tobacco is a short-growing crop requiring only a few months to obtain maturity, it appears that the decomposition of filter-press cake is not sufficiently rapid in this soil to supply the crop's heavy immediate demand for the nitrogen.

Phosphorus was also needed by tobacco, but no significant yield increases were obtained from potash applications.

The highest tobacco yields were obtained when lime was used with inorganic fertilizers (treatment 8). However, when filter-press cake was substituted to supply nitrogen equivalent to that supplied by ammonium sulphate; no such yield increase with the addition of lime was noted (treatment 7).

At present no explanation can be offered for this failure of increasing yields significantly when lime is used in conjunction with filter-press cake.

ROOT CROPS

Yams. The White Guinea variety of yam, *Dioscorea rotundata*, was grown on a Lares clay at Utuado with applications of filter-press cake. The results in Table V show no significant yield response to either filter-press cake or mixed fertilizer.

TABLE V

INFLUENCE OF FILTER-PRESS CAKE AND COMMERCIAL FERTILIZER ON THE YIELDS OF ROOT CROPS

Treatment No.	Fertilizer treatment per acre with				Yield of root crops per acre for		
	Commercial inorganic fertilizers			Filter-Press cake[1]	Yams[2]	Sweetpotatoes[3]	Yautias (dasheen)[4]
	N lbs.	P_2O_5 lbs.	K_2O lbs.	Tons	Cwt.	Cwt.	Cwt.
1	0	0	0	0	231	—	—
2	225	100	225	0	249	—	—
3	225	100	225	15	239	—	—
4	0	0	0	10	—	29	33
5	0	0	0	20	—	31	53
6	183	200	200	0	—	47	—
7	83	100	100	10	—	57	—
8	100	200	200	0	—	—	19
9	100	200	200	10	—	—	51
10	100	200	200	20	—	—	53
Least significant difference needed between treatments at :							
5-percent level					38	14	18
1-percent level					—	19	23

1. Calculated on a wet basis.

White Guinea Yam, (*Dioscorea rotundata*), grown at Utuado on a Lares clay ; 1951-52.

3. U.P.R. 3, yellow-fleshed sweetpotato grown at Loisa on a Catanio loamy sand, 1950.
4. Kelley yautia (*Xanthosoma atrovirens*), grown at the Corozal Substation on a Lares clay, 1953.

Sweetpotatoes. Filter-press cake failed to increase sweetpotato yields on a Catanio loamy sand when used alone or in conjunction with a mixed fertilizer. The use of 10 tons of filter-press cake per acre plus a mixed fertilizer (Table V, treatment 7) gave no significantly increased yields over those obtained with mixed fertilizers alone (treatment 6). Yield increases were not marked when filter-press cake was used alone (treatment 4 and 5). This soil responded to potash fertilizers. Filter-press cake lacked sufficient potash to produce high sweetpotato yields when used alone. Sweetpotatoes have a high demand for potash (2), if filter-press cake is to be used as a fertilizer for this crop it must be re-enforced with additional potash.

Yautias. Yautias, *Xanthosoma atrovirens*, Kelly variety, were fertilized with filter-press cake on the heavy Lares clay at Corozal. The use of it alone or in combination with inorganic fertilizers increased yields significantly as compared with the use of inorganic fertilizers only (Table V). Filter-press cake gave higher yields at 20 than 10 tons per acre when used alone. In combination with inorganic mixed fertilizer, 20 tons per acre of filter-press cake proved to be no better than 10. The yautias did not respond to potash applications in this experiment.

Plantains. Filter-press cake did not prove beneficial to plantains grown at the Corozal Substation on a Lares clay, 1950-51. The use of 10 tons of filter-press cake, plus 2,000 pounds of a 10-10-10 commercial fertilizer per acre gave no increase in yield over that obtained with the use of 2,000 pounds of the 10-10-10 fertilizer alone. The soil received an application of 7,500 pounds of lime ($CaCO_3$) per acre. Yields were reduced from 22 pounds of plantains per tree with commercial fertilizer to 16 pounds with fertilizer plus filter-press cake.

Pineapples. The influence of filter-press cake on pineapple yields must be re-evaluated in light of our newly-acquired knowledge of the limiting factors imposed by biological-parasitic factors on pineapple growth. Experiments conducted before adequate measures were taken to control soil nematodes, mealybugs, and other biological-parasitic factors produced variable results. On a Bayamon silty clay at Manati, 1951-53, the use of 20 tons of filter press cake per acre, plus, 2,500 pounds of a 12-6-8 mixed fertilizer, gave no increase in yields over the mixed fertilizer used alone. Hernandez-Medina *et al* (1) found that on a Bayamon silty clay at Palo Blanco, Arecibo, 1950-51, there were no significant yield increases when up to 32 tons of filter-press cake per acre were applied without mixed fertilizers. However, the use of 32 tons of filter-press cake, plus 1,500 pounds of a 12-6-10 formula, gave yields just as good as those obtained with 3,000 pounds per acre of a 12-6-10 fertilizer. A combination of 30 tons of filter-press cake and 3,000 pounds of a 12-6-10 formula was needed to produce the highest yields on a heavy Lares clay. Filter-press cake alone was insufficient.

When the soil and pineapple plants were properly treated with fumigants and insecticides to control biological-parasitic factors, filter-press cake at the rate of 20 tons per acre failed to increase yields on a Bayamon silty clay.

DISCUSSION

Filter-press cake has value as a fertilizer. However, as it is not concentrated, much more of it must be used than of inorganic mixed commercial fertilizers. But its nutrient concentration is sufficient to allow it to compete with organic fertilizer sources such as animal manures. In Table VI a comparison is made of the fertilizer compostition of filter-press cake and regularly used organic fertilizer materials. Except for its lower potash content, filter-press cake fertilizer value is better than animal manures, but it does not have as good a composition as the seed meals and animal tankages. Because of high shipping rates on imports of the bulky organic fertilizer materials, filter-press cake can be used to replace these at quite a saving in transportation costs.

TABLE VI

A COMPARISON OF THE CHEMICAL COMPOSITION OF FILTER-PRESS CAKE. MANURES AND OTHER ORGANIC FERTILIZER SOURCES[1]

Fertilizer material	Composition on a dry-weight basis for N Percent	P_2O_5 Percent	K_2O Percent
Filter-press cake	2.2	2.8	0.5
Cattle manure, shredded	2.0	1.8	2.2
Sheep or goat manure	1.4	1.0	3.0
Castor pomace	4.1-6.6	1.2	1-1.5
Cottonseed meal	6.7-7.4	2.3	1-5.2
Fish tankage	8.5-10	4.8	—
Garbage tankage	2.5-3.3	2.5	0.5-1
Sewage sludge (activated)	4.1-6.4	2.5-4	—
Tankage (animal)	5-10	3-13	—
Tobacco stems	1.2-3.3	—	4-9

When applied directly from the factory to field or garden, filter-press cake will "burn" the plants like fresh animal manure. This so-called 'burning" really results from the rapid decomposition of the new filter-press cake which liberates heat and ammonia, and other nutrients in high concentrations. Many farmers allow filter-press cake to "cure", or to complete its initial decomposition, from 6 months to 1 year before using. However, this curing is not necessary for use on field crops if the fresh filter-press cake is applied sufficiently (about 6 weeks) in advance of planting. It will then have had time to complete its initial decomposition and will prove equal to well-rotted filter-press cake.

Filter-press cake has very little residual action on the soil. It decomposes quite rapidly, releasing the bulk of its nitrogen as nitrates. The peak of nitrate formation occurs in about 5 months after it is applied to the soil (see Fig. 1). The low residual action of filter-press cake was shown very clearly in Ramirez's work (5) where different quantities up to 75 tons per acre produced appreciable yield increases in the plant cane, but failed to do so for the first ratoon crop, and proved less beneficial still to the second ratoon crop.

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[1] Chemical composition of the manures and other organic fertilizer sources adopted from (4).

The authors personally have seen applications of filter-press cake as high as 200 tons or more per acre on a sandy soil fail to produce any influence one year thereafter. Unlike lime, filter-press cake does not lend itself to a strong residual effect over a long period of time. The maximum organic matter a soil will contain under natural conditions is controlled by certain natural laws governing the soil and climate; the addition of amounts over this maximum will be wasteful in that the material added will be rapidly destroyed by the soil microflora until the natural level is reached. Therefore, unnaturally high organic levels cannot be maintained in the soil by using filter-press cake.

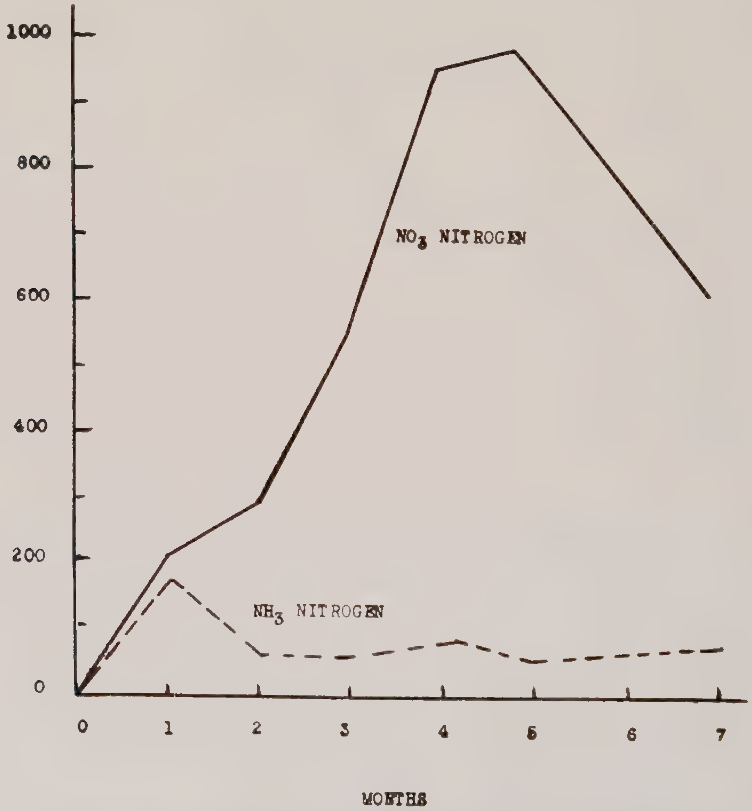

Fig. 1. Nitrate (NO_3) and ammonia (NH_3) nitrogen produced per acre over a 7-month period when 15 tons of filter-press cake per acre were added to a soil, after Ramirez (5).

When filter-press cake is available from a nearby local source, its main cost is that of transportation and application. Because of its great bulk, these costs may be high for large applications. Fresh filter-press cake contains about

60 percent of moisture by weight and even when piled at the factory and allowed to stand, the moisture runs from 15 to 45 percent. Because of its high moisture content and variations caused by place and method of storage, filter-press cake applications will vary greatly in their nutrient content. For example, a truck of 5 cubic yards capacity can haul about 2.3 tons per load of fresh filter-press cake containing 60 percent moisture by weight. This represents about 40 pounds of N, 50 of P_2O_5, and 8 of K_2O per acre in the truckload of filter-press cake. An application of 15 tons of filter-press cake (6½ truckloads) to an acre of cane land would mean that the cane would receive, in fertilizer material equivalents about 250 pounds of N, 325 of P_2O_5 and 50 of K_2O. Filter-press cake of 30-percent moisture content weighs about 1.9 tons per 5 cubic yards and it would require 8 truckloads to deliver 15 tons to a field. But now more nutrients and less water are present so that an acre of cane receiving the 15 tons of 30 percent-moisture filter-press cake would get about 450 pounds of N, 600 of P_2O_5, and 100 of K_2O.

To facilitate calculations of the volume or weight of filter-press cake at various moisture contents, Figure 2 has been constructed from experimental measurements. The N, P_2O_5, and K_2O contained in a ton of filter-press cake at certain moisture contents are also presented therein as a guide to the use of this material.

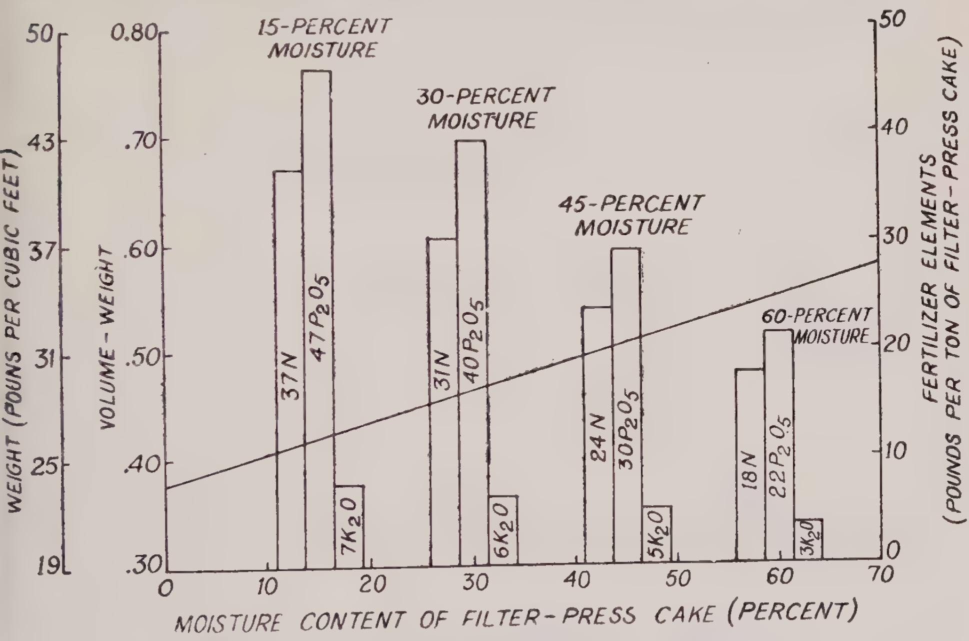

Fig. 2. Volume-weight and nutrient content (N—P_2Q_5—K_2O) of filter-press cake at various moisture contents.

In any discussion of filter-press cake it should be mentioned that it is a perfect medium for breeding insects. To kill flies, ants and other insects usually present when filter-press cake is being handled, spray it with chlordane or Aldrin. This does not interfere with its fertilizing properties at all.

SUMMARY

This study on the use of filter-press cake as a fertilizer material may be summarized as follows :

1. It is a by-product of the sugarcane mills consisting principally of a mixture of cane fibres, sucrose, coagulated colloids including cane wax, albuminoids, and phosphates of lime, plus sand and soil.
2. It is a soft, spongy, lightweight amorphous dark-brown to black material. When fresh from the filter-presses it contains about 60 percent of moisture, and about 15 percent when air-dry.
3. Its chemical composition averages 2.19 percent of N, 2.77 percent of P_2O_5, 0.44 percent of K_2O, and 3.05 percent of CaO, plus considerable quantities of the minor elements.
4. It does not produce appreciable yield increases when used on sugarcane in combination with commercial mixed inorganic fertilizer.
5. It is beneficial to tomatoes growing on a Coto clay when used at a rate of 10 tons per acre, but yields were higher when commercial fertilizer was used.
6. Ten tons per acre significantly increased yields of peppers on a Juncos clay.
7. Pigeon peas and corn responded to neither filter-press cake nor regular fertilizers.
8. Tobacco yielded more when filter-press cake was used as a nitrogen source, but ammonium sulphate produced higher yields still when used to supply equivalent amounts of N.
9. Yams did not respond to the use of filter-press cake.
10. Filter-press cake alone did not produce as good results on sweet-potatoes as commercial fertilizer.
11. Filter-press cake increased the yield of yautias.
12. Plantains did not respond to filter-press cake when grown on a Lares clay.
13. Pineapples gave a mixed response to applications of filter-press cake. When damage caused by biological-parasitic factors was properly controlled, the filter-press cake applications did not increase yields.
14. The composition of filter-press cake, as compared with that of other organic fertilizers showed it to be about equal (except for low K_2O) to animal manures but not to animal tankage or seed meals.
15. If applied about 6 weeks prior to planting the decomposition of fresh filter-press cake will not produce "burning" on vegetable crops.

PRACTICAL RECOMMENDATIONS

Filter-press cake may be used advantageously as a fertilizer material if adequate attention is paid to its limitations and full use is made of its particular advantages. Its main disadvantages are its low K_2O content and large bulk combined with low concentrations of nutrients. Its main advantages are its cheapness, slower release of nutrients, minor-element content, high water-holding capacity, high exchange capacity and mulching properties.

The following recommendations are made for its use on crops :

1. Apply yearly in small amounts rather than in very large applications once in 3 to 4 years.
2. Use more on light-textured soils than on heavy clays.
3. Use carefully on very poorly-drained soils, not applying the filter-press cake too deeply in the soil which prevents decomposition.
4. Large applications must undergo thorough incorporation into the plowed layer. Surface application and incorporation with the upper inch or two of soil is better for small applications. For root crops, application in the hole below the seed makes better use of minimum quantities.
5. Filter-press cake should be applied to fast growing crops such as vegetables and tobacco a few weeks before plantings, especially if the filter-press cake is not well rotted.
6. Filter-press cake should be supplemented with potash fertilizer when used for crops or soils with high potash demands, about 30 pounds of KCl for every ton of fresh filter-press cake containing 60 percent of moisture.
7. The maximum yearly recommendations in tons per acre for specific crops are :

Sugarcane 10, pineapple 30, root crops 20, ornamental 10 to 20, coffee 20, tobacco 10, vegetables 10, and plantains 10.

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Dr. T.S. Venkatraman presented the following paper in the absence of the author. In doing so he remarked that this was the first attempt in India on the use of liquid ammonia as a fertilizer.

Paper

ANHYDROUS AMMONIA AS A NITROGENOUS FERTILIZER: ITS USE ON SUGARCANE AND OTHER CROPS

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INTRODUCTION

The growing popularity of anhydrous ammonia as a source of nitrogen nutrition for crops in the United States prompted the author to undertake an examination of its possibilities in this country, particularly in view of its low cost and the prospects indicated with regard to a replacement of the common fertilizer ammonium sulphate whose production depends on imported sulphur or certain localised deposits of gypsum. The present paper reports results of studies conducted with reference to various aspects of the problem.

EXPERIMENTAL RESULTS

(*i*) *Small scale trials on Ragi*: Experiments were laid out in small plots in a pot culture house to compare the effects of liquor ammonia with those of ammonium sulphate, ammonium nitrate and groundnut cake at the same level of nitrogen. It will be seen in Table I that the yields of ragi grain and straw were the lowest in liquor ammonia treatment. As the soil was sandy loam, a loss of applied ammonia appeared likely and varying amounts of colloidal material (as clay) were added to the liquor ammonia treated plots. The results in Table II will show that under these conditions, liquor ammonia out-yielded ammonium sulphate treatment in a considerable measure. The above responses could be expected to hold good in case of anhydrous ammonia as well, considering that the products formed in the soil would be the same.

(*ii*) *Field experiments on paddy and sugarcane*: Field experiments on paddy were laid out at three Government farms, using 30 lbs. of nitrogen per acre as liquid ammonia and ammonium sulphate. Difference in yield of grain and straw were non-significant as between the two treatments, except in one case where liquid ammonia gave a significantly higher yield of straw (Table III). Besides these statistically laid out experiments at Government Farms, certain large scale experiments were carried out at a Model Farm in Community Project area as also in cultivators' fields. It will be seen in Table IV that both grain and straw yields were distinctly higher under liquid ammonia treatment.

TABLE I

EXPERIMENTS WITH LIQUOR AMMONIA ON RAGI IN PLOTS IN THE POT CULTURE HOUSE

	Summer 1949		Monsoon 1949		Summer 1950	
	Grain	Straw	Grain	Straw	Grain	Straw
15 lbs. of N per acre as Ammonia.	182	372	229	404	277	575
15 lbs. of N per acre as Am$_2$So$_4$	342	685	310	513	396	795
15 lbs. of N per acre as AmNO$_3$	248	460	268	418	355	770
15 lbs. of N per acre as G.N.C.	231	429	299	512	380	775
Control, no manure	180	347	205	352	241	426

Yield of ragi grain and straw in gms. per 2 sq. yards, average of 4 replications.

TABLE II

LIQUOR AMMONIA APPLIED IN CONJUNCTION WITH COLLOIDAL MATERIAL

	Monsoon 1950		Summer 1951		Monsoon 1951	
	Grain	Straw	Grain	Straw	Grain	Straw
15 lbs. of N as Am$_2$SO$_4$	212	292	526	1120	620	930
15 lbs. of N as Ammonia	202	261	506	1040	507	760
15 lbs. of N as Ammonia in conjunction with 5 tons per acre of colloidal material	257	352	623	1320	870	1320
—do—with 7½ tons per acre	231	314	600	1280	978	1530

Yield of Ragi grain and straw in gms. per sq. yard, average of 4 replications.

TABLE III

YIELD OF PADDY GRAIN AND STRAW IN GOVT. FARM TRIALS

Treatments	Hebbal Form				A.R.S. Mandya		A.R.S. Nagenahalli	
	Monsoon 1954		Summer 1954		Monsoon 1954		Monsoon 1954	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
30 lbs. of N as Ammonium sulphate	2075	4371	2043	—	3900	10,280	2914	5203
30 lbs. N as liquid Ammonia	2248	4551	1981	—	3640	17,070	2764	6019

TABLE IV

YIELD OF PADDY GRAIN AND STRAW FROM THE EXPERIMENTS AT THE MODEL FARM SORAB AND A PRIVATE FARM AT CHATRADAHALLI

Treatments	Model Farm Sorab		Chatradahalli Farm	
	Grain in pallas*	Straw in lbs.	Grain in pallas*	Straw in lbs.
Liquid Ammonia (30 lbs. N per acre)	34.8	7640	34.10	15200
Ammonium sulphate (30 lbs. N per acre)	27.33	5360	28.20	13000
Control	23.47	5547	17.50	9500

*One palla of paddy weighs about 180 lbs.

An experiment with sugarcane was also conducted at a Government Farm. The crop had a basal application of 20 cartloads compost, 224 lbs. superphosphate and 160 lbs. of nitrogen per acre as groundnut cake (half at light earthing up and half at final earthing up). The treatments consisted of 80 lbs. N per acre as ammonium sulphate and liquid ammonia divided in two equal doses, viz., at planting and 12 weeks thereafter. The yields were not significantly different under the two treatments (Table V).

TABLE V

YIELD DATA IN TRIAL WITH SUGARCANE

Treatments	Yields from Experimental area of 4.2 guntas	Acreage Yields.
Ammonium sulphate treated plots	7498 lbs.	31 tons 10 Cwts
Liquid Ammonia plots	7929 ,,	33 ,, 14 ,,

(*iii*) *Experiments on retention of ammonia by soil*: Measured doses of liquid ammonia were injected in single furrows, soil cores being collected immediately and at periodical intervals thereafter and immersed in water. The ammoniacal nitrogen estimated in the water was taken as free ammonia in the soil pores. Periodical soil samples from the furrows were also leached with sodium chloride solution and estimated for exchangeable ammonia and nitrates. The figures in Tables VI and VII afford a comparison of ammonium sulphate and liquid ammonia treatments in this regard. It would appear that a considerable time elapses before the injected ammonia gets fixed in the exchange complex. The nitrification of ammonia when applied as such will also be seen to be much more rapid

TABLE VI

ANALYSIS OF WATER EXTRACT OF SOIL (AMMONIACAL NITROGEN AS P.P.M. OF SOIL)

Treatment	Date 17-3-54	24-3-54	1-4-54	14-4-54
1. Soil sample from plots treated with liquid ammonia, Sample 1	38.0	20.8	1.3	0.0
2. Soil sample from plots treated with liquid ammonia, Sample 2	52.1	23.4	2.2	0.0
3. Soil sample from plots treated with ammonium sulphate	4.0	0.5	0.0	0.0

TABLE VII

ANALYSIS OF N IN NaCl EXTRACT (AS P.P.M. OF SOIL)

Date	17-3-54		24-3-54		1-4-54		14-4-54	
Treatment	NH_3 N	NO_3 N	NH_3 N	NO_3 N	NH_3 N	NO_3 N	NH_3 N	NO_3 N
1. Soil liquid ammonia plot, Sample 1	56.0	11.2	49.3	12.4	24.7	20.3	11.2	71.7
2. —do— Sample 2	48.0	12.5	42.6	14.6	17.9	35.6	11.2	69.9
3. Soil from ammonium sulphate treated plot	26.3	2.8	13.4	20.2	6.7	15.7	6.7	9.0

TABLE VIII

LOSS OF AMMONIA BY DIFFUSION FROM SOIL SURFACF AFTER INJECTION OF LIQUID AMMONIA INTO THE SOIL

	Interval	Volumes of decinormal HCl used up by neutralization with NH_3 from an area 1/16 sq. yard in c.c.s.	Mgs. of NH_3 which escaped from an area of 1 sq. Yd.
1st set	10 minutes	1.3	39.4
	20 ,,	1.8	49.0
	30 ,,	0.9	24.5
	40 ,,	1.2	32.7
2nd set	10 ,,	0.8	21.8
	20 ,,	1.9	51.7
	30 ,,	1.7	46.2
	40 ,,	1.4	38.1

The quantity of ammonia applied to the soil at the rate of 50 lbs. of NH_3 per acre works out to 4690 mg. per sq. yd.

than when added as ammonium sulphate and this agrees with the observations of Eno and blue, (1). In another set of experiments, the loss of ammonia by diffusion from the soil surface was measured (Table VIII). It will be seen that the loss is very small (1% of the quantity injected) and this occurs immediately after injection when the gas issues at high pressure, subsequent loss by diffusion being negligible. This is in agreement with obsrvations in other countries (2,3).

(*iv*) *Technique of application* : Equipment for application of liquid ammonia must be simple and cheap to suit conditions of farming in India. Such equipment has been devised at the workshop of the Mysore Agricultural College (Fig. 1). This consists of a valve controlling outlet of liquid from the cylinders, supported on a chassis mounted on two wheels. The flow of liquid is regulated by a pin valve and it is led through pressure hose connections into a steel tube fitted to the trailing edge of a ploughshare which cuts through the soil. The liquid ammonia gets distributed in the soil at a depth of 4"-6". Distribution in multiple rows can be effected by arranging a number of ploughshares in parallel (Fig. 2). After injection the liquid ammonia is covered over by a coulter fixed at a distance from the injector. An equipment for row crops has also been devised (Figs. 3 and 4). This is mounted on a chassis running on two wheels and has 2-4 ammonia injectors. A less expensive device is to mount the ammonia cylinder on a cart drawn by bullocks behind which a single injector is hinged on to the longitudinal beam of the cart. This equipment is particularly suitable for injection in rows after the crop has grown to some height as in case of sugarcane.

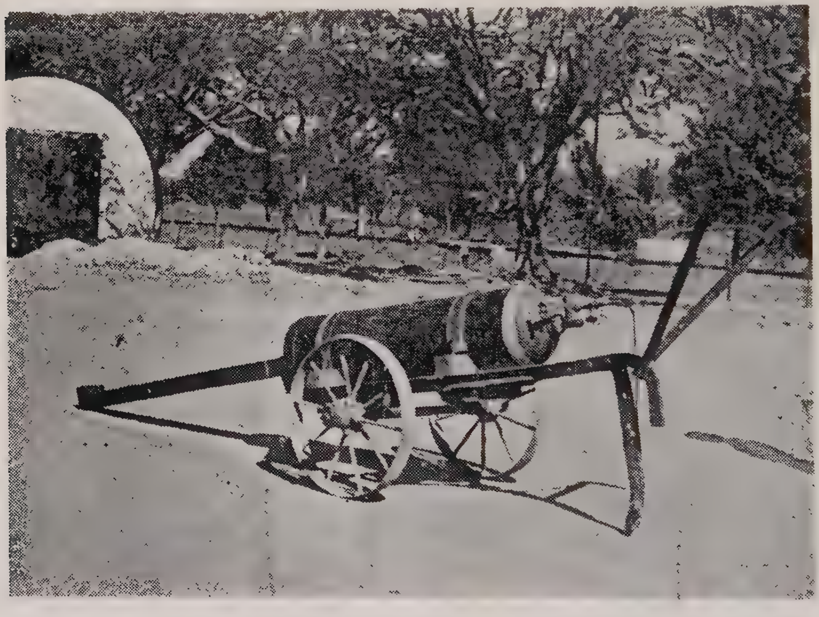

Fig. 1. Liquid Ammonia Applicator showing valve arrangement.

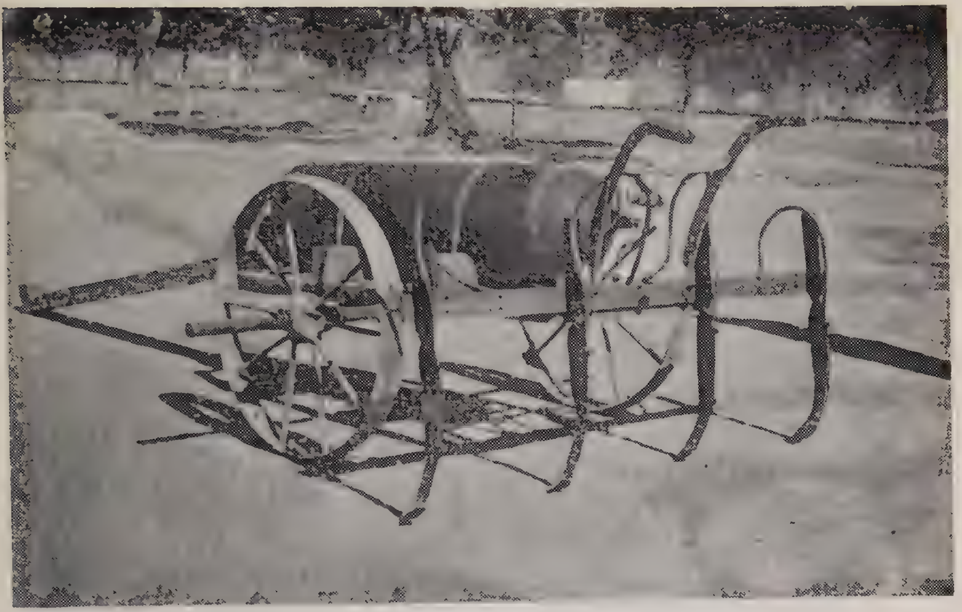

Fig. 2. Liquid Ammonia Applicator fitted for multiple row application.

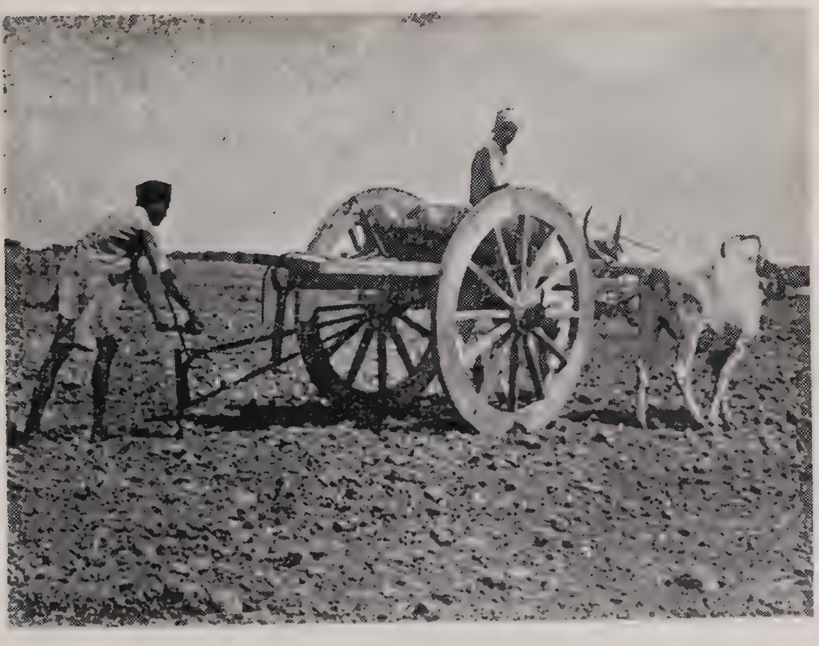

Fig. 3. Liquid Ammonia Applicator mounted on bullock cart.

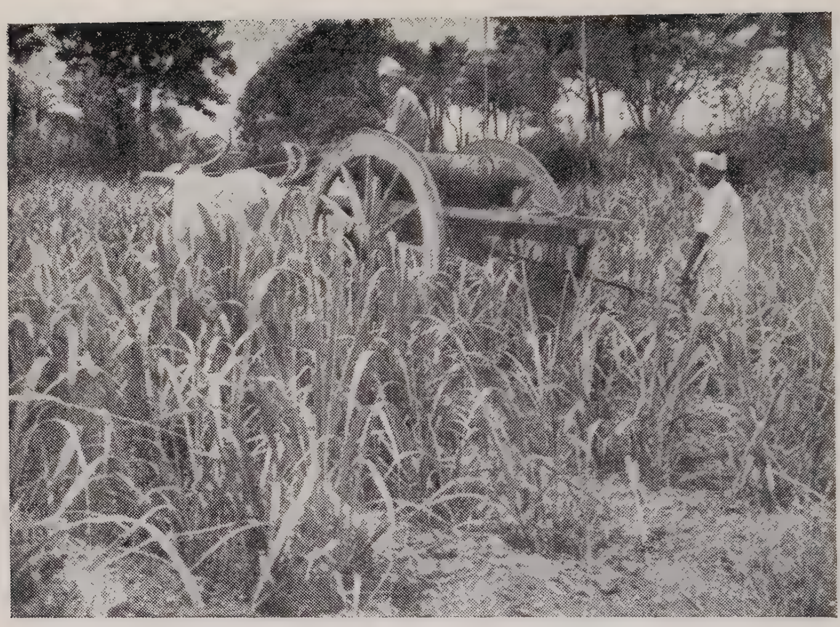

Fig. 4. Liquid Ammonia being injected along the rows in a sugarcane field.

For wet crops like paddy, liquid ammonia is applied partly in irrigation water. A simple device consists of a 4 gallon tin with opening at the bottom and one side embedded in the inlet channel, the ammonia issuing from the control valve being let in at the bottom of the water column in the tin through a flexible tube. The ammonia dissolves quickly with no loss to the atmosphere and the required quantity is applied by regulating the valve.

DISCUSSION

The results of these studies would appear to indicate possibilities with regard to use of liquid ammonia in place of common fertilizers like ammonium sulphate in as much as it gives roughly the same crop yields at a considerably lower cost. It is retained in the soil almost completely and undergoes more rapid nitrification than ammonium sulphate. Suitable equipment already devised at the Mysore Agricultural College would render its adoption a practical proposition. Due care must, however, be exercised in the use of anhydrous ammonia so as to avoid injury to people handling it.

SUMMARY

Anhydrous ammonia is retained almost completely in the soil and undergoes more rapid nitrification than ammonium sulphate. It affords crop yields

of the same order as the latter and is therefore preferable in view of its cheapness. Equipment for its application to the soil has been devised which is cheap and suited to Indian conditions.

ACKNOWLEDGMENTS

The work in this State on the use of liquid ammonia as a fertilizer has received impetus from the drive given to it by Dr. R. Naganna Gowda, M. Sc., Ph. D., Minister for Agriculture and the enthusiasm and faith shown by him in its utility as a fertilizer. The simple types of mechanical equipment for injection and application of ammonia, described in this paper are largely the result of efforts by Mr. Venkatarangiah, Chemist, Mysore Chemicals and Ferlilizers Ltd., Mr. K. N. Dwajan, Agricultural Engineer, Mr. S.H. Thimmappa, Lecturer in Mechanical Engineering, Agricultural College and Mr. A. Gopalappa, Superintendent, Central Industrial Workshop, Bangalore. The assistance given by Mr. B. Dasappu, Principal, Agricultural College, Hebbal, Mr. B. Bhim Rao, Assistant Agricultural Chemist and Mr. B.V. Venkata Rao, in the conduct of the field experiments and laboratory analysis are gratefully acknowledged.

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Dr. R. K. Tandon presented the following paper.

Paper

TIME OF APPLICATION OF NITROGENOUS FERTILIZERS TO SUGARCANE

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INTRODUCTION

It has long been recognised that the Indian soils are deficient in nitrogenous reserves. Therefore, need for supplying nitrogen to heavy feeding crops like sugarcane is obvious. Considerable work has been done to find out the optimum dose of nitrogen required by this crop and as Burns (1944) stated 'a stage had reached when the optimum dose could be recommended with confidence and the main question was how most economically to apply that dose'.

Nitrogen is very mobile. It is lost by leaching and run off, and under certain conditions as gaseous ammonia rather quickly. The speed with which this loss occurs depends upon several factors, e.g., the form in which it is applied, the agricultural practices and the time available for decomposition. For making the most economic use, it is important that the manures should be applied at a time when they can be used by the crop to its best advantage.

Experiments have been conducted at the Sugarcane Research Station, Shahjahanpur in Uttar Pradesh for well over two decades with a view to find out the most suitable time of application of nitrogen to the sugarcane plant crop both in the form of organic and inorganic manures. But it is only during the last three seasons that experiments have been conducted on this aspect on ratoon crop. It is proposed to discuss the results of these experiments in this paper.

EXPERIMENTS WITH PLANT CANE

Sethi (1937) found that the best yields are obtained when the fertilizers (ammonium sulphate at 60 lbs. N per acre+superphosphate at 45 lbs. P_2O_5+ potassium sulphate at 45 lbs. K_2O per acre) are applied at planting or early during the tillering period. Later application at the break of rains not only gave lower yields of cane but also delayed maturity of cane to some extent. Experiments on the time of application of ammonium sulphate (60 lbs. N per acre) over basal farmyard manure, (40 lbs. N per acre) to plant cane conducted at Shahjahanpur during 1944-45 to 1947-48 (Annual Reports 1944-45, 1946-47 and 1947-48) showed no significant differences between the applications in a single dose and in 2, 3 or 5 piecemeal doses. In general, application in one dose at the time of planting seemed to be the best.

In a similar series of experiments with castor cake (at 60 lbs. N per acre over a basal dressing of farmyard manure @ 4 lbs. N per acre) also, the piecemeal application did not prove of any advantage over the application in a single dose, four weeks before or at planting time. The same results were obtained in a third series of experiments in which castor cake alone at 100 lbs. N per acre was applied.

In another series of experiments conducted on light loam soil at this station during 1944-45 to 1946-47, Saxena (1951) found that the early application of nitrogen in a single dose induces larger number of tillers per acre than piecemeal applications and that the number of millable canes and consequently yield of cane per acre were also higher under single dose treatment. On juice quality, piecemeal applications proved to be better than single dose treatment up to a dose of 100 lbs. N per acre but reverse was the case under heavier dose of nitrogen.

EXPERIMENTS WITH RATOON CROP

In this series, time of applications of nitrogen to ratoon had been studied in relation to two other factors, viz., systems of planting and systems of harvesting plant cane.

The treatments were:

1. Time of application of nitrogen.

A: Full dose (120 lbs. N per acre) so on after harvest of the plant cane crop.

B: Full dose (120 lbs. N per acre) at the break of rains.

C: Half dose at harvest of plant crop as under A and half dose at the break of rains as under B.

D: Control (No manure).

II. Systems of planting cane.

F: Flat system; T: Trench system.

III. Systems of harvesting cane.

R: Harvesting plant cane at ridge level followed by dismantling of ridges.

G: Harvesting of plant cane at ground level after dismantling ridges.

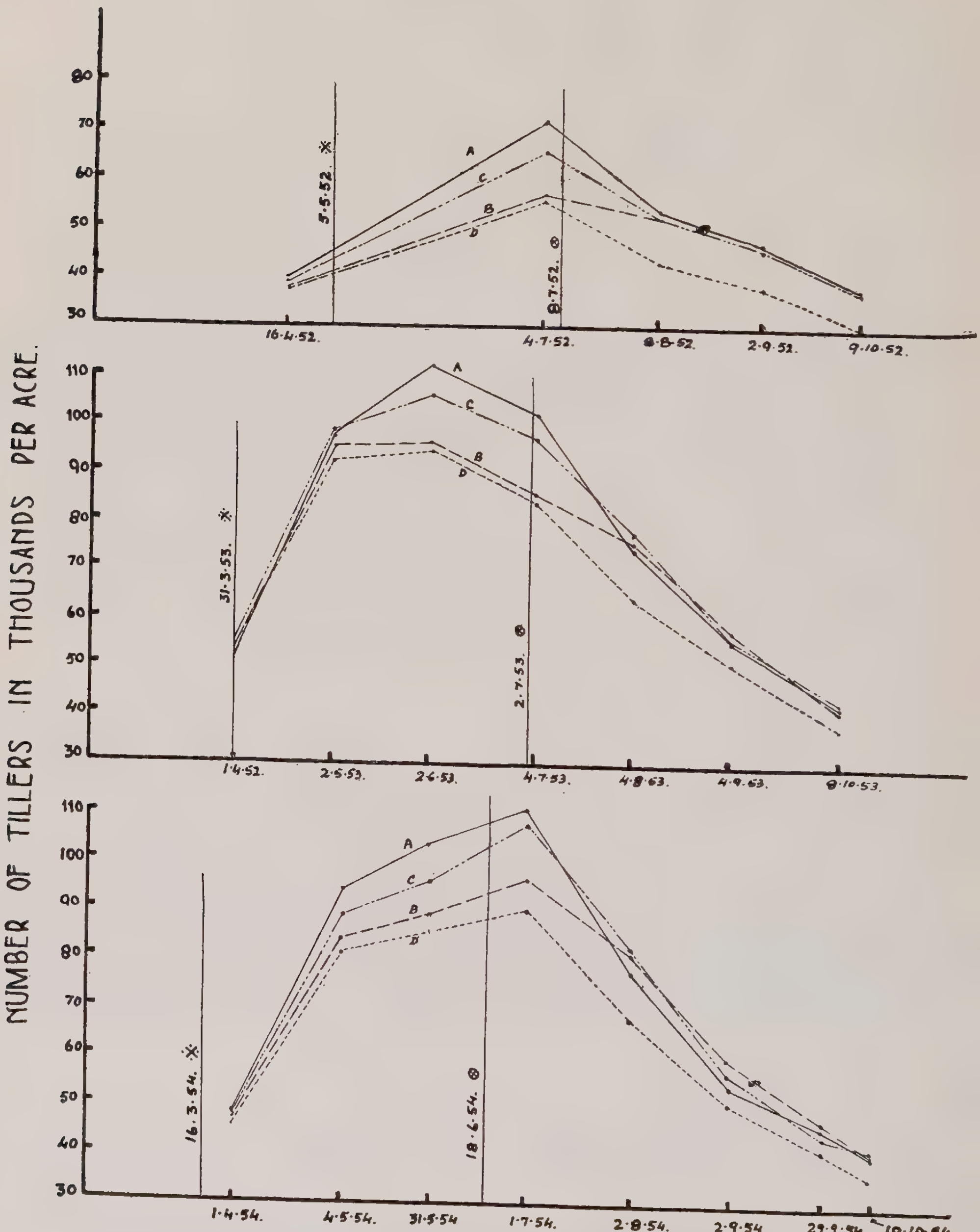
The experiment was laid out in a split plot design with main plots to the combination of systems of planting and systems of harvesting treatments and sub-plots to the time of application of nitrogen to ratoon crop. There were 4 replications each season. The variety of cane tried was Co. 453. The plant crop was supplied with the normal dose of 120 lbs. N per acre, 80 lbs. N per acre in the form of green manure and farmyard manure + 20 lbs. N per acre as groundnut cake + 20 lbs. N per acre as ammonium sulphate. For the ratoon crop under investigation, the manure was applied in the form of groundnut cake and ammonium sulphate in the ratio of 50 : 50 nitrogen basis. This was followed by irrigation to the entire experimental plot. In A and C treatments manuring was done either just before or after the first irrigations and mixed up in the soil by hoeing. Normal irrigation and hoeing, viz., 3-4 irrigations and 6-8 hoeings were given to the ratoon crop each season. The remaining half dose of nitrogen in treatment C and the full dose in treatment B were given towards the break of rains according to programme.

Observations were taken on tillering, millable canes per acre, yield of cane and juice quality.

Tillering :—The first counting of the number of tillers produced per acre under different treatments was done at the time of early application of manures i.e., full dose in A and the 1st half dose in C treatment. The succeeding counts were taken at monthly intervals till the month of October during all the seasons, except in 1952-53 when countings during the month of May and June could not be taken. Due to the absence of data for these months the actual progress in tillering during the summer of 1952 cannot be correctly gauged. However, it is clear that the trend of the results so far as the effects of the manurial treatments are concerned was similar (Fig. 1) in the different years (Table I).

Fig. I. SUGARCANE I YEAR RATOON.

EFFECT OF TIME OF APPLICATION OF NITROGEN ON TILLEERING.



※ DATES OF MANURING:- FULL DOSE TO 'A' AND HALF DOSE TO 'C' TREATMENTS.

⊗ DATES OF MANURING:- FULL DOSE TO 'B' AND HALF DOSE TO 'C' TREATMENTS.

TABLE I

COMPARATIVE NUMBER OF TILLERS AND MILLABLE CANES PER ACRE UNDER DIFFERENT MANURIAL TREATMENTS

(a) At the time of application of first instalment of manures (early application)

Treatments	Tillers (in thousands) per acre I Year 16.4.52	 II Year 1.4.53	 III Year 1.4.54	Average
A	40.0	51.8	47.0	46.3
B	39.1	55.3	46.5	47.0
C	39.4	54.8	46.9	47.0
D	38.5	54.6	45.4	46.2

(b) At the time of second instalment (late application) of manures

Treatments	Tillers (in thousands) per acre 1 Year 4.7.52	 II Year 4.7.53	 III Year 31.5.54	Average.
A	71.9	102.2	103.5	92.5
B	57.3	85.6	89.0	77.3
C	65.7	97.4	96.0	86.4
D	55.9	84.3	85.8	75.3
S.E.	±1.530	±2.353	±2.041	±1.134

(c) At about 1 to 1½ months after second instalment (late application) of manures

Treatments	Tillers (in thousands) per acre I Year 8.8.52	 II Year 4.8.53	 III Year 2.8.54	Average
A	54.2	74.7	77.6	68.8
B	51.8	74.6	80.7	69.0
C	52.3	77.6	81.7	70.5
D	43.4	63.9	68.3	58.5
S.E.	±1.062	±1.695	±1.230	±0.783

(d) Number of millable canes per acre under different manurial treatments

Treatments	No. of millable canes (in thousands) per acre I Year 9.10.52	II Year 8.10.53	III Year 10.10.54	Average
A	38.1	42.5	41.1	40.6
B	37.4	41.9	41.2	40.2
C	37.6	43.3	41.2	40.7
D	30.5	38.1	36.5	35.0
S.E.	±0.607	±0.673	±1.053	±0.463

(e) Survival percentage-millable canes expressed as percentage of the peak number of tillers obtained during each season

Treatments	I Year	II Year	III Year	Average
A	53.0	38.0	37.0	42.7
B	65.3	43.8	42.7	50.6
C	57.2	40.9	38.3	45.5
D	54.6	40.2	40.8	45.2

At the first counting (Table I-a) the treatment differences were negligible but as the season advanced treatment A showed highest number of tillers closely followed by treatment C. Treatments B and D which received no manure so far, indicated the least progress (Fig. 1).

The data (Table I-b) collected about the time of late application of manures (full dose in B and the second half dose in C treatment), revealed that the treatment A gave significantly higher number of tillers per acre than treatment C. Both treatments A and C were significantly superior to B and D.

Reduction in the net number of tillers set in from about the beginning of rains in June-July. From Fig. I it is apparent that this reduction was greatest under A and least under B treatment. As a result the data (Table I-c) on the number of tillers available during the month of August, i.e., about a month after the late application of manures revealed that treatment B was as good as treatment A or C while D (no manure) treatment remained significantly inferior to all the other treatments.

This relationship between different treatments was more or less maintained till the end of the season, the number of millable canes (Table I-d) showing no significant differences between A, B and C treatments while no manure treatment D was significantly inferior to the 3 manurial treatments.

In order to study if the differences in the reduction of shoots between different treatments (Table I-e) were due to the differences in the mortality of tillers or in the production of new tillers or both, all the shoots of 3 clumps in each plot during the season 1954-55 were tagged after the fertilizers had been completely applied to different treatments and the peak number of tillers had been attained. Observations were taken for emergence and mortality of shoots at the time of successive monthly countings. The results showed that a few new tillers did come out during this period but the differences between different treatments in this respect were not marked. It is clear therefore that treatment B made up for its millable canes and equalled the treatments A or C chiefly through better survival of the tillers.

Yield of millable canes

The entire area of each plot after excluding border crop of 3 ft. area all-round was harvested about the middle of December each season. The data are presented in Table II.

TABLE II

YIELD OF MILLABLE CANES PER ACRE

Treatment.	1952-53 Yield of cane in Mds.	 Percentage on control	1953-54 Yield of cane in Mds.	 Percentage on control	1954-55 Yield of cane in Mds.	 Percentage on control
A	708.9	162.4	716.4	158.0	680.1	146.4
B	679.8	155.7	670.9	148.0	712.7	153.4
C	706.9	161.9	699.3	154.2	674.8	141.4
D	436.5	100.0	453.4	100.0	464.5	100.0
S.E.	±13.4	—	±14.6	—	±15.3	—

The results show that application of fertilizers at 120 lbs. N per acre has on an average increased the yield of ratoon cane by 242.8 mds. per acre which is 53.8 percent higher than control (no manure). The response of ratoon to the manures applied works out to about two maunds per lb. of nitrogen added. Regarding the effects of manurial treatments (A, B and C) on the ratoon yields it may be observed that during the first two years A and C gave higher yields than treatment B but during the third season treatment B gave slightly higher yields than A and C. However, the differences between the manurial treatments A, B and C were statistically non-significant except during the season 1953-54 when the treatment A was significantly superior to treatment B (Table II). The interaction between time of application of nitrogen and systems of planting or harvesting cane were also not significant.

Juice quality:—Plotwise analysis of cane juice from different treatments was done for sucrose and purity thrice during the period from October to December each season. As in the case of other characters already discussed, there were no significant interactions between manurial and planting or harvesting treatments in juice quality also. There were, however, marked differences in juice quality due to different times of application of nitrogen. The average results for each season are given in Table III.

TABLE III

AVERAGE JUICE QUALITY (SUCROSE PER CENT JUICE)

	Average sucrose percent juice (October-December)			
Treatments	1952-53	1953-54	1954-55	Average
A	15.17	15.44	13.56	14.72
B	13.94	14.50	13.39	13.94
C	14.51	15.15	13.47	14.38
D	15.39	15.49	13.92	14.93
S.E.	±0.108	±0.087	±0.068	

The results have consistently shown that late application of nitrogen at the break of rains (treatment B) results in significantly inferior juice quality as compared to early application (Treatment A). Treatment C wherein half the dose of nitrogen was applied early at the harvest of plant crop and the remaining half dose late at the break of rains, has given intermediate results as expected. It is interesting to note that in spite of an increase in the yield of cane by 250 mds. per acre due to early application of nitrogen in full dose over control (no manure), there was no marked difference in the average juice quality (October-December) between the two treatments except in 1954-55 when there were abnormally heavy rains as late as the beginning of October and the crop had partially lodged.

TABLE IV

AVAILABLE SUGAR PER ACRE

	1952-53		1953-54		1954-55		Average	
Treat-ments	Available Sugar in mds. per acre	Percentage on control	Available sugar in mds. per acre	Percentage on control	Available sugar in mds. per acre	Percentage on control	Available sugar in mds. per acre	Percentage on control
A	72.49	158.7	74.17	156.5	61.12	142.0	69.26	152.69
B	62.91	137.7	64.63	136.4	63.04	146.5	63.53	140.10
C	68.54	150.0	70.90	149.6	60.04	139.5	66.49	146.58
D	45.68	100.0	47.38	100.0	43.03	100.0	45.36	100.0

In sugar per acre (Table IV) calculated on the basis of Winter and Carp modified formula* treatment A has proved to be markedly superior to the other treatments; treatment B, which had given almost as good yields of cane as the treatments A or C, has proved to be much inferior in this respect to either of these treatments, the difference in favour of treatments A and C over treatment B being 5.73 and 2.96 mds. of sugar per acre respectively. As compared with no manure

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*Available sugar percent cane $=S-0.4(B-S)\ X\ 0.73$

Where $S=$sucrose percent juice, $B=$Brix corrected.

(D) treatment, the three manurial treatments, A, B and C have on an average given 53, 40 and 47 percent higher or 23.90, 18.17 and 21.13 mds. respectively more of available sugar per acre.

DISCUSSION

Plants absorb solutes from soil solution according to passive or physical as well as active or physiological laws of diffusion of solutes through a cell membrane. Thus plants are not only able to absorb solutes to meet their immediate needs but they are also able to take up and accumulate salts in excess even beyond the stage of equilibrium on the two sides of the cell membrane (Miller 1938). It has been shown (Kobus 1900, Ayres 1937, Pramanik *et al* 1937, Yuen and Borden 1937, Anon 1941, Clements and Moriguchi 1942, Rege and Basu 1944, Borden 1945), that nitrogen is taken up most rapidly during the first few months in the life of the crop. This may be in quantities far in excess of the immediate needs of the plants and may be utilized for thier later growth. The following remarks of Willcox quoted by Dutt (1950) appear interesting in this connection, "Some recent work tends to show that a cane field might as well be given all the fertilizer it needs at the start instead of at intervals even when the crop duration is 20 months or longer. It is shown that the plants will absorb all the necessary plant food in the first 4 months".

Experimental evidence is, however, available to show that the most suitable time of nitrogen fertilization depends on the amount of nitrogen required by the crop, its availability and the age at which the crop is harvested (Borden 1945). This is further complicated by the environmental conditions pertaining to soil and climate under which cane is grown as well as the agricultural practices followed. For instance, it has been suggested (Moir 1935) that open porous soils with poor water holding capacity require smallar doses of nitrogen applied oftener while fine silt soils can stand heavier applications. Dodds and Colepepper (1940) pointed out that under light soils nitrogen should not be applied until the cane crop is well established and at least several inches high. Under Shahjahanpur conditions, where about 3-4 irrigations only are given to the sugarcane crop during the formative period no great loss of nitrogen due to leaching down possibly occurs during this period even under loam or sandy loam soils. Significant loss of nitrogen, however, is expected during monsoon period particularly under light soils. The capacity of sugarcane crop to absorb nitrogen in excess of its immediate needs early in the season before serious loss of nitrogen during monsoon occurs, is, therefore, of particular significance under these conditions. In general, early application of nitrogen improves yields of cane through better tiller production and their early growth, while late application makes up tonnage to a great extent through better survival of tillers already formed and continued growth late in the season. Therefore, under short growing seasons as is normally the case under Uttar Pradesh conditions, early application of nitrogen at or near the start of the crop is generally found to give better yields of cane compared with late application. It is only during exceptional years of prolonged growing period as we had during the season 1954-55, that late application of nitrogen at the break of rains may give better yield of cane than early application. In juice quality early application of nitrogen proved better than late or piecemeal applications apparently because nitrogen when present in plenty, late in the season (as happens to be the case with late application treatments) consumes sucrose, which would otherwise have been stored in the plant, to form cellulose and lignin required for the growing tissues. These results, in general, are in agreement with the findings of various workers (Verret 1927, Alexander 1928, Das 1931, Borden 1940, Cornelison and Cooper 1941) who concluded that the fertilizers should be applied well ahead of the harvesting season for ensuring good yields and sugar per acre as late applications of nitrogen delayed the maturity of cane.

SUMMARY AND CONCLUSIONS

With a view to finding out the most suitable time of application of nitrogen to sugarcane crop, experiments on replicated basis have been conducted with plant cane at the Sugarcane Research Station, Shahjahanpur, for well over two decades. It is only during the last 3 seasons (1952-53, 1953-54 and 1954-55) that a series of experiments on the first year ratoon has been conducted at this station. The results with plant crop have been reviewed by various authorities (Sethi 1937, Rege 1941, Mukerji and Verma 1950) from time to time. These have, therefore, been mentioned here only very briefly in order that the results obtained with ratoon crop discussed in detail in this paper may be more intelligible. The conclusions which can be drawn from these experiments on plant cane as well as on the ratoon may be summarised as follows.

With plant crop the trend of the results has been that early application of nitrogen at or near planting time gives higher yield of cane and better juice quality than piecemeal applications although the differences have not come out statistically significant in many cases. Since castor cake takes longer time to decompose and make nitrogen available to the plants as compared to ammonium sulphate, it is desirable to apply the oilcake 4 weeks before or at planting time and ammonium sulphate at the time of planting or soon after the completion of germination.

In the case of ratoon, early application of nitrogen in full dose at the time of harvest of plant crop (treatment A) induced markedly greater tillering than the treatment C wherein half the dose had been applied early and the remaining half late at the break of rains. The latter (treatment C) in its turn produced higher number of tillers per acre than treatment B under which all the nitrogen was applied late at the break of rains.

In survival percentage of tillers the results obtained were just the reverse, treatment B giving least mortality of tillers followed in order by C and A treatments. As a result, the 3 manurial treatments A, B and C did not show any significant difference in the number of millable canes.

In yield of cane per acre, early application of nitrogen at the start of the ratoon crop proved superior to late application except during the season 1954-55 when the growing period was unusually long due to prolonged rainy season. The differences between early and piecemeal application in two doses was not significant during any of the 3 seasons.

All the manurial treatments were statistically superior to treatment D (no manure) in the number of tillers, millable canes and yield of cane per acre. The average increase in yield of cane due to the application of 120 lbs. N per acre to the ratoon crop, was of the order of 243 mds. per acre or 54 percent over no manure (control). The response of the crop to nitrogen applied works out to about 2 mds. of cane per lb. of nitrogen added.

Late application of nitrogen at the break of rains delayed maturity of cane more than any other treatment. It is interesting to note that in spite of an increase in yield by about 250 mds. of cane per acre due to an early application of nitrogen over control (no manure) there was no marked difference between the two treatments in the average (October to December) sucrose percent juice during normal seasons.

In sugar per acre, treatment A was found to be best followed in order by C and D treatments. These manurial treatments on an average gave an additional yield of 21.1 mds. of sugar per acre or 46.5 percent higher than the control (no manure).

From these results it may be concluded that when the dose of nitrogen applied is of the order of 120 lbs. N per acre its application in a single dose at the start of the ratoon crop would be the best practice. Alternatively the fertilizer may be applied in two doses, half dose at the start of the crop and the other half at the break of rains. It is not desirable to postpone application of the entire dose of nitrogen to the time of break of rains.

ACKNOWLEDGMENT

The authors wish to express their thanks to the Indian Central Sugarcane Committee which partly finances the Sugarcane Research Station, Shahjahanpur, where the experiments described in this paper were carried out.

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Dr. Arakeri presented the following paper

Paper

ROLE OF COMPOST IN SUGARCANE CULTURE

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INTRODUCTION

Organic matter is considered as the life of soil although it has been possible to grow healthy plants in sand culture without any organic matter. Organic matter is supposed to help in maintaining physical and biological condition of soil and also in supplying all or at least some of the essential plant nutrients. Bulky manures like compost and Farm Yard Manure are added to soil mainly to maintain organic matter at a certain level. With all the expermientation the world over, the value of bulky manure in agriculture is still undecided (6, 9). Cooke and Garner (3) have reviewed the work done in England and they have stated that there is still much research to do before the role of organic matter is understood fully. The necessity of adding basal manure to sugarcane crop where large quantity of root material is left over in the soil is still a widely discussed question (1, 7, 8).

In Bombay State the tendency of sugarcane grower has been to add bulky manures especially Farm Yard Manure in as large a quantity as possible and top dress with any available oilcake (recently groundnut cake). To assess the role of bulky manure and to examine the possibility of replacing the groundnut cake with ammonium sulphate as top dressing material, an experiment was started in 1939 at the Sugarcane Research Station, Padegaon, Bombay State. Results obtained upto 1950 have been reported elsewhere (5). After 1950 the experiment was modified and the results obtained after modification are presented in this paper.

MATERIALS AND METHODS

An experiment having 12 treatments had been laid down in 1939 with randomised block design in 'B' type of soil classified according to the genetic method of soil classification (2). The treatments included no top dressing and top dressing material consisting of only groundnut cake or ammonium sulphate and different ratios like 1 : 1, 1 : 2, 2 : 1 of ammonium sulphate and groundnut cake. One set of these treatments received basal dressing of 20 thousand lbs. of compost per acre and the other did not receive any basal dressing. The rotation followed has been Groundnut-Cane-Sorghum and the same initial randomisation has been maintained to study the long range cumulative effects on soil and plant growth. Compost was applied before planting sugarcane. Top dressing material was applied in varying doses to supply 300 lbs. of N per acre.

After the completion of 4 cycles (each cycle of three years) each plot in no compost group was split into two and one of the two sub-plots is being treated since then with N.P.K. equivalents of 20 thousand lbs. of compost per acre in the form of inorganic fertilizers. The manurial value of compost in terms of N, P and K when analysed came to 120 lbs. N, 120 lbs. P_2O_5 and 650 lbs. K_2O. The nutrients were supplied in the form of Ammonium Sulphate, Superphosphate and Sulphate of Potash. Potash content of compost is higher because of the use of ash in preparing compost.

Periodical morphological observations were taken and harvest data was collected every year. The detailed biochemical studies were carried out in few of the treatments. Soil studies were also carried out to assess the effect on physical and biological properties of soil.

TABLE 1

EFFECT OF TOP DRESSING CANE WITH DIFFERENT RATIOS OF SULPHATE OF AMMONIA AND CAKE WITH AND WITHOUT BASAL DRESSING OF COMPOST ON YIELD FOR THE YEAR 1939-40 TO 1949-50.

AVERAGE OF 4 REPLICATIONS

	With Compost					Without compost					C.D.
	Cake alone	S/A alone	S/A & cake 1:1	S/A & cake 1:2	S/A & cake 2:1	Cake alone	S/A alone	S/A & cake 1:1	S/A & cake 1:2	S/A & cake 2:1	for significance
I Cycle (Average of 3 years)											
Cane in tons per acre	56.91	55.43	58.84	58.85	56.59	54.95	47.69	56.88	57.47	55.05	4.20
Percent	96.7	94.2	99.9	100.0	95.9	93.3	81.0	96.6	97.6	93.5	
II Cycle (Average of 3 years)											
Cane in tons per acre	47.32	36.57	45.29	46.08	42.18	43.86	24.50	37.13	41.22	32.15	2.96
Percent	80.4	62.1	76.9	78.3	71.6	74.5	41.6	63.0	70.0	45.6	
III Cycle (Average of 3 years)											
Cane in tons per acre	45.92	31.46	44.38	45.64	38.52	42.20	20.41	36.44	39.68	28.88	3.74
Percent	78.0	53.4	75.4	77.5	65.4	71.7	34.6	61.9	67.4	49.0	
IV Cycle (Average of 3 years)											
Cane in tons per acre	50.11	44.14	47.22	51.54	50.49	40.35	21.26	33.92	36.16	27.35	3.12
Percent	85.0	75.0	80.2	87.5	25.7	68.5	36.1	57.6	61.4	46.4	

RESULTS AND DISCUSSION

The yield data from first four cycles are given in Table I.

It can be seen that the results have been very striking in that the yields have gone down considerably in the absence of compost whereas in the compost group cumulative effect of applying compost is observed in all the treatments at the end of 4th cycle. From this data it was concluded (5) that compost plays an important role in sugarcane culture from the standpoint of its cumulative effect although it hardly contributes to the supply of N.P.K. nutrients to the crop immediately after its application. It was also concluded that in the absence of bulky manure the top dressing should be in the form of cake alone as the fall in yield in this treatment was minimum.

As stated already the experiment was modified in 1950, to ascertain whether the effect of compost was purely physical and biological or the depressing effect in no compost group could be prevented by supplying mineral equivalents of compost in inorganic forms. Since then the experiment has completed one cycle and yields obtained per acre are given in Table II.

TABLE II

EFFECT OF MINERAL EQUIVALENTS OF COMPOST IN THE FORM OF INORAGNICS ON THE YIELD OF CANE AS COMPARED TO COMPOST AND NO COMPOST, SUPPLEMENTED BY TOP DRESSING MATERIAL WITH VARYING RATIOS OF SULPHATE OF AMMONIA AND CAKE. (AVERAGE OF 4 REPLICATIONS AND ONE CYCLE OF 3 YEARS)

			Cane tons per acre			
Group	No manure	S/A alone	S/A 2:1	to 1:1	Cake 1:2	Cake alone
No compost	11.1	17.5	25.4	32.5	35.6	39.0
No compost modified (Mineral equivalents of compost)	26.8	43.7	43.9	44.6	48.3	48.5
% Increase over no compost	140.8	149.8	72.9	37.2	35.7	24.4
Compost	20.8	29.3	38.5	39.2	45.3	44.4
% Increase over no compost	87.4	67.4	51.6	20.6	27.3	13.9

It is interesting to observe that there is an over all increase in the mean yields of all treatments in the no compost group treated with mineral equivalents over the no compost group and to a certain extent over the compost group also (without mineral equivalents). This is attributable to the deficiencies of N.P.K. being made up by mineral equivalents. The effect of mineral equivalents is highly pronounced. The low level of yields in the no compost group treatment of sulphate of ammonia and its higher proportion can be ascribed to the deficiency of P and K. This deficiency on being made up by application of mineral equivalents has resulted in raising the yield per acre even higher than compost group. The percentage increase is not so much in the treatment with cake alone or higher proportion of cake probably because cake supplies some quantity of P and K in addition toN. The data thus indicate that the effect of compost appears to be more of a chemical nature than a physical or biological one.

Sheath and leaf samples from different treatments were periodically analysed during two years for the mineral constituents. The data are presented in Table III.

In treatments A, G_1 and G_2 not supplied with nitrogen top dressing, a clear nitrogen deficiency is indicated in spite of compost or its mineral equivalents in the first two treatments. Phosphorus index of treatments A and G_2 are also not satisfactory. These factors thus appear to limit the yields in these treatments. On applying nitrogen top dressing either as sulphate of ammonia or cake, the nitrogen index has come up but phosphorus index has continued to remain low. In treatment I, top dressed with sulphate of ammonia, the phosphorus index is at its optimum. The only source of phosphate in this treatment is the superphosphate included in the compost mineral equivalent. Compost itself, however, is not so efficient in supplying phosphorus but when supplemented by cake it becomes adequate (treatment B and C). It can be seen that potassium index in different treatments is at optimum throughout the growth period. It is also not benefitted by the application of 650 lbs. of K_2O in the form of potassium sulphate.

When no nitrogen top dressing is applied, compost supplies to a limited extent both N and P. With sulphate of ammonia as nitrogen top dressing, better yields are obtained in compost group probably because of supply of phosphorus from compost. The supply of phosphorus being inadequate in these treatments the yields are lower than those obtained in the treatments receiving compost minerals, containing superphosphate. It can also be seen that groundnut cake supplies appreciable quantity of phosphate. From this it appears that the main role that the compost is playing in sugarcane culture under Deccan (Bombay) conditions is to supply phosphorus and that too with limited efficiency and when this is supplemented with cake as nitrogenous top dressing material it produces optimum yields.

Effect on physical and biological properties of soil studied are already presented elsewhere (4). The data show that the application of compost is beneficial in improving the soil fertility in general and humus status and physical condition of soil in particular. It also brings about enhancement in the microbiological activity measured in terms of total bacterial count, nitrification and soil respiratory activity.

CONCLUSION

The results of a long range experiment to ascertain the role of compost in sugarcane culture are presented. Following are the conclusions drawn:—

1. The yields of sugarcane go on dropping as years go by, if no compost is applied even if the crop is top dressed to supply 300 lbs. N per acre and regular 3 years rotation is followed. When the top dressing treatments are compared amongst themselves the depressing effect is less when the top dressing material

TABLE III

NUTRIENT INDICES AT DIFFERENT STAGES OF GROWTH (VALUES IN PARENTHESIS ARE FOR THE CROP OF THE SUBSEQUENT YEAR)

Crop age in months	Compost			Compost Minerals			No basal		
	No N.T.D. (A)	Gr. Nut cake (B)	Sul. of Ammonia (C)	No N.T.D. (G_1)	Gr. Nut Cake (H_1)	Sul. of Ammonia (I_1)	No N.T.D. (G_2)	Gr. Nut cake (H_2)	Sul. of Ammonia (I_2)
				Nitrogen Index (N percent in dry matter of leaves)					
4	0.77	1.20	1.19	0.86	1.16	1.02	0.85	1.26	1.22
6	0.83	1.27	1.19	1.04	1.16	1.19	0.84	1.23	1.18
7	0.80	1.27	1.32	0.88	1.18	1.06	0.83	1.02	0.93
8	0.79	1.31	1.27	0.89	1.24	1.28	0.94	1.21	1.18
	(0.87)	(1.20)	(1.28)	(1.01)	(1.19)	(1.24)	(0.87)	(1.21)	(1.19)
9	—	1.20	1.06	0.88	—	1.15	1.03	1.12	1.53
	(0.69)	(0.93)	(0.89)	(0.77)	(0.92)	(1.03)	(0.72)	(1.03)	(0.95)
11	0.60	0.59	0.54	0.62	0.69	0.38	—	0.60	0.62
	(0.62)	(0.79)	(0.80)	(0.60)	(0.98)	(0.93)	(0.76)	(0.73)	(0.91)
				Phosphorus Index (P per cent in sheath dry matter)					
4	0.08	0.09	0.05	0.06	0.07	0.08	0.04	0.05	0.04
6	0.05	0.06	0.04	0.06	0.07	0.08	0.04	0.06	0.04
7	0.06	0.06	0.04	0.05	0.06	0.06	0.04	0.07	0.04
8	0.10	0.08	0.06	0.06	0.08	0.05	0.05	0.06	0.05
	(0.06)	(0.09)	(0.06)	(0.07)	(0.06)	(0.08)	(0.06)	(0.08)	(0.06)
9	0.08	0.09	0.07	0.09	0.08	0.09	0.06	0.08	0.06
	(0.07)	(0.07)	(0.06)	(0.06)	(0.08)	(0.07)	(0.06)	(0.08)	(0.04)
11	0.05	0.07	0.05	0.04	0.07	0.07	0.04	0.05	0.04
	(0.05)	(0.06)	(0.04)	(0.06)	(0.08)	(0.07)	(0.04)	(0.06)	(0.04)
				Potassium Index (K percent in sheath dry matter)					
4	2.38	2.43	2.20	2.28	2.16	2.14	2.21	1.96	2.05
6	2.53	2.43	2.74	3.24	3.29	3.39	3.15	2.64	2.67
7	3.20	2.82	3.25	3.34	3.49	3.23	3.29	3.28	3.56
8	2.55	2.85	3.26	3.17	3.23	2.54	2.57	2.67	2.88
	(3.43)	(3.24)	(3.34)	(3.66)	(3.19)	(3.34)	(3.50)	(3.76)	(3.84)
9	3.04	2.52	2.76	3.78	3.79	3.67	2.93	2.78	2.59
	(3.82)	(3.04)	(3.19)	(3.22)	(3.39)	(3.56)	(3.58)	(3.10)	(2.99)
11	1.38	2.23	1.92	1.66	2.68	2.37	1.75	1.72	1.67
	(1.40)	(1.75)	(2.04)	(1.77)	(2.49)	(2.52)	(1.70)	(1.92)	(1.67)

consists of only cake or high proportion of cake as against high proportion of ammonium sulphate or only ammonium sulphate.

2. The drop in yields appears to be due to deficiency of phosphate. There is no indication to show that the deficiency of K was a limiting factor in any of the treatments.
3. It appears that it is possible to maintain the yields at a high level by applying mineral equivalents of compost in inorganic form especially phosphorus as superphosphate.
4. It is observed that compost treated plots show better status in regard to physical and biological properties of soil. It is therefore necessary to watch the long range effect of substituting compost with artificials on crop yields.

ACKNOWLEDGMENTS

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DISCUSSION

Replying to a question by Dr. Raheja, the author said that ammonium sulphate was more suitable than F.Y.M. for the cane crop.

Foliar Diagnosis and Crop Logging

Dr. Evans presented the following paper

Paper

SOME CONSIDERATIONS AFFECTING THE INTERPRETATION OF FOLIAR DIAGNOSTIC ANALYSIS UNDER BRITISH GUIANA CONDITIONS

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REVIEW OF LITERATURE

The utilization of mineral analyses of various selected tissues for the determination of optimal nutritional status in sugarcane has expanded considerably during the last decade. Craig, Halais and Feillafe (1938-1953) have been closely associated with the adoption of foliar diagnosis as a routine control of manurial practice in Mauritius; Innes (1949-1953) and his colleagues in Jamaica; Du Toit (1953) in S. Africa; Beauchamp (1940) in Cuba; Bedsole and Breggar (1953) in Florida; Aughtry and Lunin (1953) in the Dominican Republic ; Bonnet, Samuels, Capo and Bangdiwala (1953) in Puerto Rico; Ayres, Borden, Hance, Clements. Burr and Humbert (1933-1954) in Hawaii and Evans and his colleagues (1954) and Birkett (1954) in British Guiana.

The considerable success of the technique in many of these territories was to some degree due to the fact that every effort was made to eliminate or render ineffective certain known variables the effects of which might otherwise be difficult to interpret.

In Mauritius, for example, it was stressed that leaf samples would be taken only at the steep part of the sigmoid growth curve of sugarcane in taht territory and moreover only when the climatic conditions of temperature and soil moisture were optimal. It was specified that even within the boom growth period, no disturbing effects such as cyclone or drought had occurred for 3 weeks or more immediately prior to sampling.

Similar restrictions on the time of sampling have been made in most other territories where the technique is used.

The variations in climatic conditions even at comparable periods of the year, e.g., fluctuations in rainfall from year to year or differences in temperature due to altitude or seasons have been shown to have substantial effects particularly on the nitrogen content of the leaf. In addition it is accepted everywhere that age of the plant as a whole has a significant effect on leaf nitrogen even where the selected leaf is always morphologically comparable.

Samuels, Capo and Bangdiwala (1953) have emphasized the importance of moisture and age as the main controlling variables of foliar nitrogen content in Puerto Rico. Burr (1952-1953) and his colleagues in Hawaii emphasized the importance of temperature and light intensity and particularly the temperature of the root environment on foliar nitrogen.

From a consideration of the literature briefly reviewed above, it may therefore be concluded that foliar nitrogen is particularly subject to the influences of environment.

Clements (1953) has described a somewhat different approach to the problem of sugarcane nutrition and his crop-log technique is familiar to most sugarcane technologists. In so far as nitrogen is concerned however, he also has selected foliar nitrogen for the nitrogen index.

With respect to potash, those who have used foliar potash content for diagnostic purposes are generally eminently satisfied with its reliability: those who, like Clements, have used the potash level in the sugar-free dry matter of the elongating leaf sheaths for diagnostic purposes are also satisfied that this index is reliable. From this one might tentatively conclude that potash level must be less affected by age and climatic conditions than is that of nitrogen.

With respect to phosphorus those who have restricted the sampling of foliar material to the "boom" period of growth when climatic conditions are favourable find the phosphorus index quite satisfactory for the diagnosis of phosphorus status. In the crop log technique the definition of phosphorus status has not been very satisfactory except during the boom period and even at that time is frequently considered to give a less reliable evaluation of the P—status than potash does of the K—status.

Burr (1954) and his colleagues using tagged phosphorus showed that air and root temperatures had a very marked effect on uptake of phosphorus. These workers consider that the cane stalk, and in particular internodes 8-10 (counting from the apex) form the best indicator tissue of phosphorus utilization and have also established that the mature part of the stalk and the older foliage are far more sensitive to potassium deficiency than are the younger green foliage and the elongating green stalk.

SOME GENERAL CONSIDERATIONS

The sugarcane plant must be regarded as a dynamic unit in which by reason of various levels of metabolism different concentrations of elements are maintained in the various tissues. Some parts of the plant—the stalk and leaf sheaths in particular—accumulate elements which may be regarded as storage reserves in that a considerable proportion—though not all—of the amount present may be drawn upon by tissues with a higher level of physiological activity. The growing region of the stem and the actively functioning leaves and young tillers are examples of tissue systems with a higher level of metabolism.

It is almost inevitable, however, that there will be a degree of correlation between the levels of an element in various tissue systems, i.e., under conditions of starvation the general level of the element in short supply will be lower in all tissues, and under conditions of excess there will be a relatively higher level in all tissues. It is for this reason that rapid tissue tests are extremely useful under conditions of marked deficiency or excess. In normal sugarcane cultivation with a reasonably efficient standard of agriculture such extremes would not indefinitely remain undiscovered.

It should be emphasized also that a tissue the analysis of which is best correlated with the analysis of the stool as a whole is by no means, of necessity, the best diagnostic tissue. In fact Plant Physiologists have, for decades, been attempting to correlate nutritional requirements with whole plant analysis with very little success. That the tissue selected shows a high correlation in mineral content with that of the whole plant should not therefore, be regarded as 'a priori' evidence in favour of the selection of such a tissue for diagnostic purposes. The elongating leaf sheath tissue selected by Clements for his crop log diagnosis of various elements was nevertheless selected on this basis.

In our view the tissue which is best suited for diagnostic purposes is that which, with due consideration for good quality in the cane, is best correlated with the yield of sugar per acre per annum. Burr (1954) and his colleagues are inclined towards another basis for the selection of a suitable tissue namely that tissue which shows the greatest differences in the content of the element in fully nourished as compared to starved plants. It will be readily appreciated that this procedure is also an indirect one and is subject to certain severe limitations.

Let us assume that a given element is utilized in greatest quantity in the leaf for the production of sugar per acre and that to fulfil this function with the greatest efficiency a concentration of $x\%$ in the foliar tissue is required. Let us also assume, as in Fig. 1A, that when the given element is applied in adequate amount not only is a concentration of $x\%$ or more, maintained in the leaf but in addition considerable storage of the element occurs in certain regions of the stalk, e.g., in Burr's diagnostic tissue—stalk internodes 8-10 and in the leaf sheath. In the event of the element becoming inadequate it would be expected that the storage reserves in internodes 8-10 or even in the leaf sheaths would show a far larger drop than the content in the leaf blade where the material was being utilized, as shown, in Fig. 1B. Moreover on the present assumption that the predominant effect of the element on sugar production per acre was exerted in the leaf, then so long as the content in the leaf did not fall below $x\%$, however much the storage tissue, (e.g., stalk internodes 8-10 or leaf sheaths) was depleted the yield of sugar per acre would remain unaffected. We would thereby have examples of tissues which would be far more sensitive to a given deficiency but which would still be of limited value as diagnostic tissues.

On the other hand if, as has been assumed, the content of $x\%$ in the leaf is critical then a small decrease below $x\%$ may well reduce the yield of sugar per acre very considerably. In this instance one would have to conclude that the foliar tissue although subject to much smaller variations than certain more "sensitive" tissues would nevertheless be a far more satisfactory tissue for diagnostic purposes.

This conclusion would however, be subject to the proviso that the variations were, nevertheless, large enough to be measured with the required degree of precision. It could be the case for example that the function of potassium, in say, the meristematic tissues of the growing point might be so vital that this tissue had the largest mobilizing power for potassium and would thus show the least reduction in potassium content under conditions of deficiency. This reduction would be of crucial importance but because of its low magnitude might well be difficult to measure with precision and as a result another tissue might well be more suitable for diagnostic purposes.

It is true, of course, that the illustrations which have been taken postulate extreme conditions since there is no element the function of which is confined

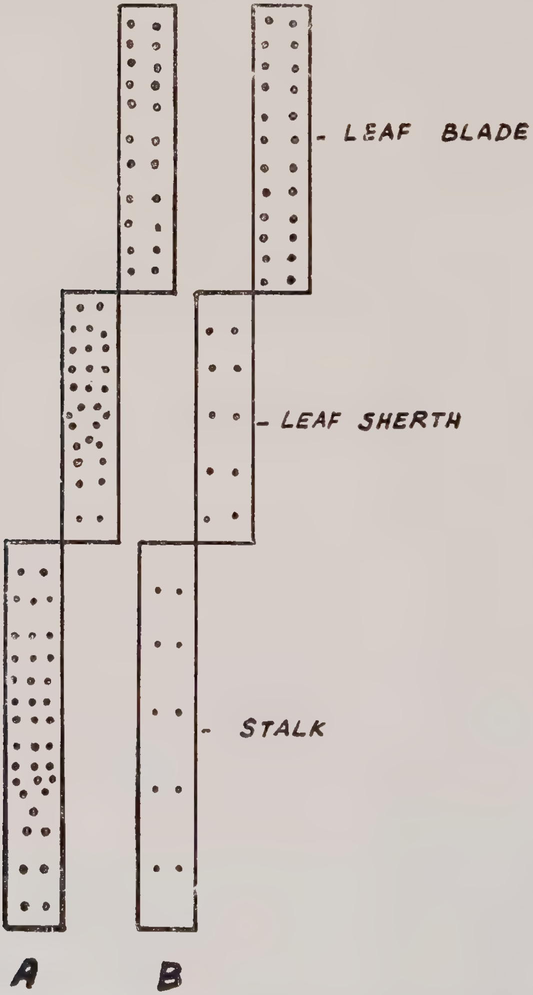

Fig. 1. Diagrammatic representation of cane plant well supplied with nutrients (A) and less well supplied (B). For interpretation see text.

to one tissue—but the argument still holds in that there is every indication that the maintenance of high leuels is far more important in some tissues than in others.

There is ample evidence that the distribution of a mobile element in the various tissues is in the nature of a partition dependent upon the intensity of metabolic activity, and it is therefore to be expected that a tissue may not be able to extract the whole amount of an element from a tissue with a lower tempo of physiological activity. This is shown by the fact that even abscised leaves falling to the ground as trash take with them fair quantities of such mobile elements as nitrogen, potassium and phosphorus.

The diagnostic value of a tissue which is particularly sensitive to short supply of a given element is that it may give advanced warning that the uptake of the element concerned is not keeping pace with its mobilization during growth and that if this condition continues a stage may be reached when the concentration of the element may fall, in the tissues where it is utilized, to levels which limit the rate of growth.

The ideal diagnostic data would provide a simultaneous assay of the nutrient in question in all parts of the plant but the provision of this data would be impracticable on a field scale. One has therefore to resort to the use of whatever tissue proves most suitable for the diagnosis of mineral deficiencies in their effect on the yield of sugar per acre.

It will be noted that the diagnostic tissues selected by Clements (with the exception of that for nitrogen) and by Burr and his associates, viz., elongating leaf sheaths and the 8th-10th internodes of the stalk respectively, are predominantly storage tissues in contrast to the tissue used in foliar diagnostic analysis which is the assimilating region of the most active leaves. In selecting storage tissue alone and arranging to maintain adequate storage reserves the diagnostician would be ensuring that there would be no likelihood of a deficiency arising but in so doing would be likely to exceed the economically justifiable rate of application. In the case of elements which are either immobile or are only very slowly mobile such as calcium or magnesium and most micro-nutrients the determination of the amounts in the storage tissues may be misleading since translocation of such nutrients may be too slow to deliver an adequate supply at vital centres when conditions militate against uptake from the soil.

We have, for example, encountered numerous cases of sudden and acute deficiency of both calcium and boron in cane in British Guiana. The onset of the conditions which bring about unavailability are so sudden that there is no time for the development of the typical starvation symptoms in the older leaves, and translocation from storage tissues to the apical tissues and to the young leaves appears to be negligible. The growing point and the spindle leaves are seriously affected and may die before supplies of the missing elements become available.

Whilst newly absorbed nitrogen, potassium and phosphorus may be expected to be completely mobile there is evidence that only a small proportion of previously assimilated nitrogen may be quickly available to other tissues.

In the case of potassium the cane in the Berbice province of British Guiana is almost invariably well supplied, indeed the content of potassium both in leaves and in sheaths may often be above the optimal values. Potassium deficiency is common in Eastern Demerara and frequent in Western Demerara. It is of interest to note that in cane grown in Berbice the Clements potassium index is almost invariably at 2.2% K or more and leaf potassium at 1.3-1.5% K or more. The type of result which is frequently met with in Western Demerara is exemplified in the following simultaneous analysis of sheath and foliar tissue. The data are from 3N× 3P× 3K factorial trials, the three levels of potash were 0, 1½ cwts. and 3 cwts. muriate of potash/acre.

TABLE I

TRIAL D. K. 46 W B. 37161

Age	K % dry matter foliar tissue			K % sugar-free dry matter of elongating leaf sheaths		
	K_0	K_1	K_2	K_0	K_1	K_2
12 weeks	1.11	1.18	1.27	1.11	1.51	1.69
19 weeks	1.16	1.24	1.29	1.36	1.69	1.72
26 weeks	1.11	1.24	1.23	1.33	1.82	1.81
Final yield of sugar/acre		K_0	K_1			K_2
K_0=100		100	111			117

TABLE II

TRIAL D. K. 83E B. 37161.

	Foliar index.			Sheath index		
	K_0	K_1	K_2	K_0	K_1	K_2
12 weeks	0.93	1.12	1.13	0.92	1.22	1.32
19 weeks	0.99	1.09	1.12	0.91	1.18	1.19
26 weeks	1.09	1.17	1.20	0.86	1.07	1.18
Final yield of sugar/acre		K_0	K_1		K_2	
K_0=100		100	106.5		112	

If Clements's critical value of 2.25 %K in the sheaths is considered adequate, then it is apparent that under the degrees of deficiency represented in these two fields the foliar tissues have proved capable of drawing heavily on the sheath tissue.

The degree of deficiency indicated by the foliar tissue (where the adequacy level is 1.2%K) would be regarded as slight to moderate : that indicated by leaf sheath would presumably be regarded as extremely severe. The indications from foliar analysis are, on the basis of the final yield results, more realistic.

FOLIAR ANALYSIS AND ITS INTERPRETATION

British Guiana being located close to the equator has relatively small seasonal variations in temperature. Effects of low root temperatures on the uptake of nitrogen and phosphate described by the Hawaiian workers are not operative under local conditions. There is little doubt that the main variable is rainfall and a second factor which interacts strongly with rainfall is soil physical conditions. High rainfall on well drained, well flood-fallowed front-land clays will have different effects on mineral uptake from high rainfall on silty clays of poor structure and on ill-drained pegassy clays.

The conditions under which most of the trials on which the results of this work are based were reasonably well drained frontland clays.

The foliar analysis have been related to the yield of cane and sugar per acre from a large series of 3N x 3P x 3K factorial trials with split plots for limestone versus no limestone; from a similar series of 3Px3Kx3Mg trials with split plots for trace element supplements versus no trace elements ; from some 3Px 3Kx3Ca factorial trials, and from varied series of other fertilizer trials.

With the prevailing climatic factors it is considered that cane yields of 60-70 tons per acre per annum in plants and 55-60 tons in ratoons are very good under average soil conditions, although a maximum yield of 92 tons cane/acre/annum in plants has been obtained exceptionally, and could probably be obtained more frequently with particularly good drainage and improved tilth.

It has been found that such high yields of plant and ratoon cane are only obtained when foliar analyses show certain specific levels of the major nutrients in the tissue sampled. The requisite levels and the factors which affect such levels are discussed below. In determining the effect of rainfall, the rain falling in the four weeks prior to sampling has been shown to bear a closer relation to the foliar analytical data than rainfall during periods longer or shorter than this.

NITROGEN

The ideal nitrogen curve for plant cane is shown in Fig. 2. The nitrogen-age regression curve does not differ significantly from a straight line passing through

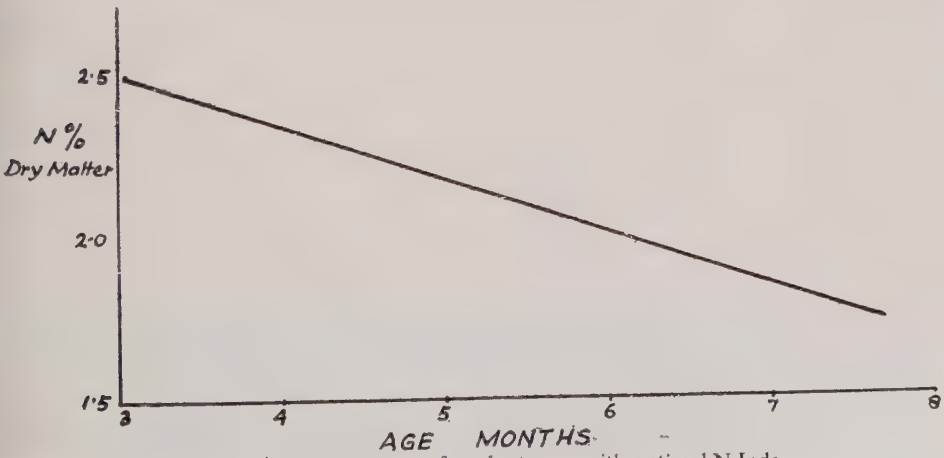

Fig. 2. Nitrogen-age curve for plant cane with optimal N Index.

the points 2.5%N at 3 months, 2.25%N at 4½ months, and 2.0%N at 6 months. It is probable that the maintenance of the requisite level within the period between 3 months and 6 months is critical and it would appear reasonable to conclude that if the nitrogen-supplying power of the soil with or without added nitrogenous fertilizer is sufficiently good to maintain the required level during this period then it will continue to do so for the whole course of growth.

It has been possible to confirm the relationship shown in Fig. 2 in that the foliar nitrogen content of a large number of commercial cane fields yielding over 60 tons of cane per acre conformed to this relationship. Birkett (1954) sampling at 16-18 weeks concluded that the foliar nitrogen index for plant cane should be 2.25%.

The ideal nitrogen curve for ratoons is distinctly different from that of plant cane and consists of a logarithmic type of curve (Fig. 3) passing through the points 2.5-2.6%N at 2 months, 2.0%N at 3 months, 1.75%N at 4 months, 1.65%N at 5 months. It would appear that the maintenance of the requisite level of foliar nitrogen within the period 2-5 months (from the date of cutting the previous crop) is critical in the case of ratoons. Birkett (1954) has found a nitrogen content of 2.25% at 10-12 weeks and 1.75% at 16-18 weeks to be associated with optimal yields in ratoons.

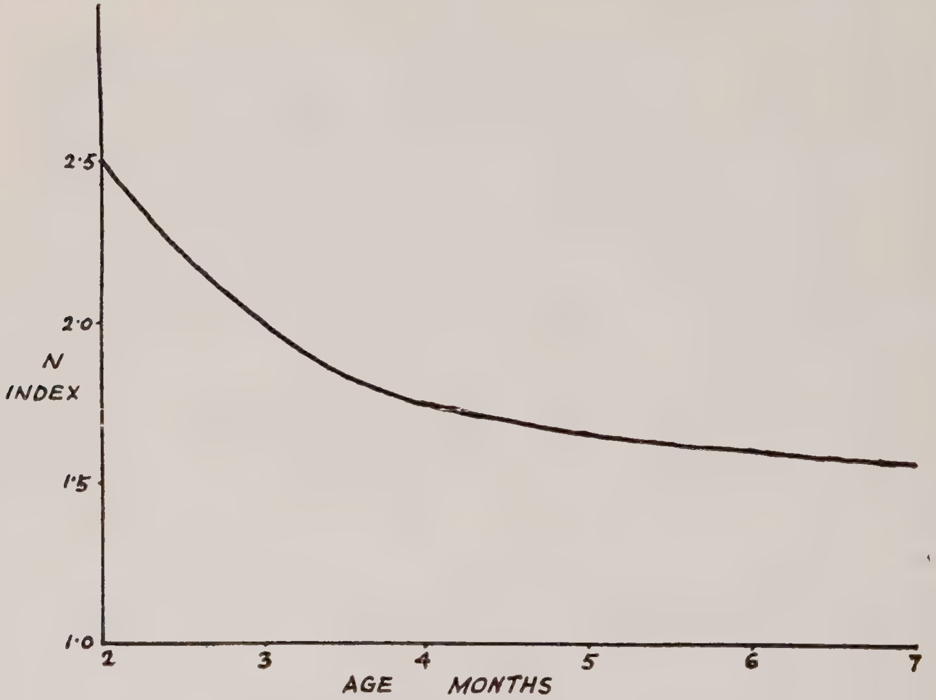

Fig. 3. Nitrogen-age curve for ratoon cane with optimal N Index.

Although workers in many countries have found the critical levels of foliar nitrogen to be somewhat different in different varieties we have, to date, been unable to establish any significant differences between varieties in this respect. It is of interest to note also that in the absence of disease there is no marked difference in the commercial performance of the Barbados varieties under extensive cultivation in the colony.

It may well be that the basic critical levels may not be different in different varieties but varieties probably differ in their response to varying external factors, e.g., in their varying capacity to maintain levels of mineral nutrients on soils inadequately supplied or under unfavourable climatic conditions.

EFFECT OF RAINFALL ON FOLIAR NITROGEN CONTENT

The general rates of application of nitrogen are in the vast majority of cases optimal. For example in some 200 fertilizer trials where normal nitrogen dressings were compared in the presence and absence of potash, phosphate and lime with dressings of nitrogen 50% larger than normal the mean increase in sugar per acre resulting from the extra nitrogen, was only 0.05 ton.

During the last two years routine foliar diagnosis has been carried out on a large number of fields on each estate as the cane came into the age group 4½-5 months. The data from these analysis have been utilized in the first place to determine the over-all effect of rainfall on foliar nitrogen at this age for all categories of cane.

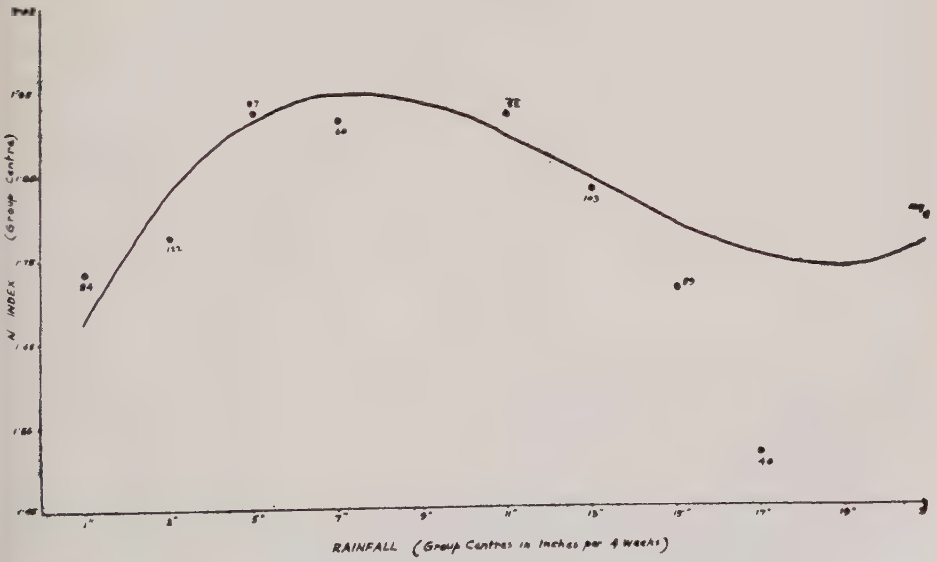

Fig. 4. Effect of rainfall on foliar nitrogen content

The results are plotted in Fig. 4 the cipher at each point representing the number of fields sampled in each rainfall range and on which each point is based.

Fig. 4 shows some points of considerable interest. The foliar nitrogen content reaches its maximum value when the rainfall during the four weeks preceding sampling was in the range 5-9 inches. There was a drop in the index with deficient rainfall being very considerable when the monthly rainfall prior to sampling was below 5 inches.

The effect of inadequate rainfall in reducing the foliar nitrogen index is, of course, generally known. Under British Guiana conditions, it is evident that rainfall in excess of 11 inches per month also greatly reduces the foliar nitrogen index, having a similar effect on the nitrogen index as inadequate rainfall.

It is for this reason that we consider that the effect of rainfall on mineral status cannot be considered alone but unquestionably interacts highly with the soil on which the cane is growing. Drought effects begin to show up quite early on the front land clay because of the superficial root system resulting from inadequate soil aeration and the presence of a high water table. On the other hand slightly excessive rainfall because of its effect on soil aeration, on root function, on leaching of nutrients and possibly on soil micro-biological activity has an immediate effect on the foliar nitrogen index. Fig. 4 merely indicates the average effect of defective and excessive rainfall on the typical frontland clay. Certain other soil-types—in particular the silty clay soils which 'pack' and lose structure rapidly under heavy rainfall conditions would probably show a greatly accentuated effect on nitrogen index. Indeed we see progressively increasing symptoms of nitrogen starvation appearing in heavy weather on such soils leading to almost complete stoppage of growth and with catastrophic effects on yields of cane and sugar. These interactions of soil and rainfall on the nitrogen index should not be regarded as a short-coming in the nitrogen index as such—it is merely that these interactions act as a potent growth factor which not only causes a decline in the nitrogen index from its optimal value but in so doing causes a similar decline in yield of cane and sugar. Insofar as these deleterious effects can be reduced, e.g., by lowering the water table producing improved tilth and improved drainage—so reducing the effect of extreme rainfall conditions or by supplementary applications of nitrogen —possibly by foliar sprays to compensate for reduced uptake under excessive rainfall conditions, so will a closer approach to maximum yields be attained.

PHOSPHORUS

The optimal foliar phosphorus index derived by Mauritius workers has been found to be applicable in several other countries: the value of the index is 0.45-0.50% P_2O_5. (0.20-0.22%P).

Under British Guiana conditions it was found that whereas most of the high yielding plots conformed to this phosphorus index, examples occurred where equally high yields were obtained with a lower index. It was noticed during routine analyses throughout the year that foliar phosphorus levels in general fluctuated according to rainfall, being generally considerably lower when dry weather preceded the sampling.

There does not appear to be an age effect on foliar phosphorus index at all comparable with that on the nitrogen index. At least at ages 3 months, 4½ months and 6 months we have no conclusive evidence of any significant differences in the foliar phosphorus index. Rainfall appears to have been preponderantly responsible for the differences found. Experiments are in progress to determine whether age changes between 3 and 6 months have any effect on the index when the soil moisture variable is eliminated.

For foliar material within the age group 3-6 months from plots adequately supplied with phosphorus a regression has been worked out between the P index and the inches of rainfall in the 4 week period preceding sampling. The relationship between adequate foliar phosphorus and rainfall is given by the equation.

$$P = 0.00498 \ R + 0.1577$$

where R is the rainfall in the previous 4 weeks in inches and P is the phosphorus content in the leaf material expressed as the element P.

This relationship which is plotted in Fig. 5 applies to plant cane : it signifies that the optimal foliar index 0.45-0.50% P_2O_5 (=0.20-0.22%P) adopted by many sugarcane growing territories applies equally to British Guiana providing that rainfall is adequate during the 4 weeks prior to taking the leaf samples—adequate rainfall being a minimum total of 8-9″ for the four weeks. Under conditions of drought (1″ of rain or less in the 4 weeks prior to sampling) the adequate foliar index is 0.157% P. Where, as in British Guiana, rainfall is the main variable this relationship has been of outstanding value in correctly defining phosphorus status. We have ample evidence that acute phosphorus deficiency cannot be corrected in the field unless rainfall is adequate.

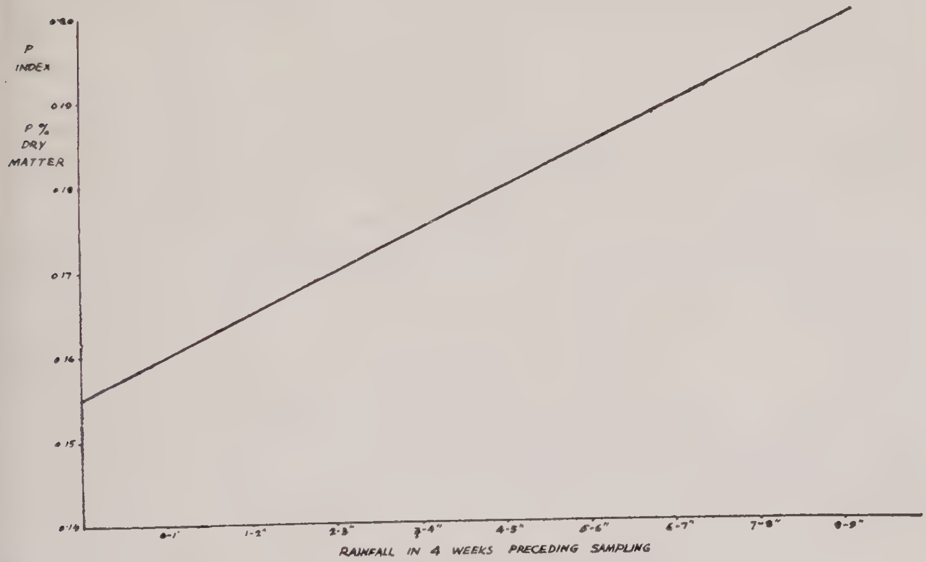

Fig. 5. Effect of rainfall on phosphorus Index

On the typical frontland clay phosphorus uptake is not so sensitive to excessive rainfall as nitrogen uptake but there is nevertheless considerable evidence for a fall in the P index when the rainfall in the 4 weeks preceding sampling exceeds 20 inches, the index being constant, in the presence of adequate phosphorus, between 8 and 20 inches monthly rainfall. Here again we should emphasize that the deleterious effect of excessively heavy rainfall on the phosphorus uptake from the silty clays is much more serious than it is on the frontland clays. Although our data on the phosphorus status of ratoon cane has not yet been completely analysed there are indications that the critical value for plant cane applies also to ratoons at least when the ratoons are young (8-10 weeks after harvesting of previous crop) but that there may be a fall in the P index with age.

POTASSIUM

The main areas of British Guiana which respond to potash are mostly confined to Demerara and are generally more severe on the pegassy and silty clay soils but frequently occur on frontland clays also. Applications of moderate amounts of potash fertilizer bring up the foliar index to adequacy. The adequacy level has been determined to be 1.20% K (1.45%K_2O). The mean value of the index from several hundred plots involving differential potash fertilization are given below.

TABLE III

MEAN VALUE OF K INDEX (% OF DRY MATTER EXPRESSED AS THE ELEMENT K)

Age at sampling	Plants			Ratoons		
	K_0	K_1	K_2	K_0	K_1	K_2
3 months	1.19	1.31	1.33	1.12	1.21	1.24
4½ months	1.24	1.34	1.38	1.16	1.21	1.28
6 months	1.28	1.36	1.34	1.22	1.26	1.28

EFFECT OF RAINFALL ON 'K' INDEX

Rainfall during 4 weeks preceding sampling	0—4″	4″—8″	8″—12″	over 12″
K index	1.28	1.33	1.34	1.31

These values are the mean of all analytical data from the whole colony each value being based on a minimum of several hundred analyses and a maximum in the case of the rainfall effects of well over a thousand. There would appear to be a slight increase in the K index in plants between 3 months and 4½ months but thereafter the index is constant. The differences are so small, however, that it would be quite in order to take diagnostic samples at any time between 3 and 6 months. The mean effect of rainfall on the frontland clays is very slight and for all practical purposes, negligible.

This however, does not rule out the existence of a very deleterious effect of excessively high rainfall on silty clay of poor structure. In fact in one extreme example of such an effect the potassium index was down to 0.4%K and the cane showed visual symptoms of potassium deficiency. When this soil dried out and cracked in dry weather the K index rose to 1.0%K without the addition of any potash fertilizer.

In other than these extreme cases of relatively rare occurrence the potassium index is remarkably constant and subject to very little interference by external conditions.

CALCIUM

It is only within recent years that the practical importance of clacium as a nutrient rather than in its usual role of soil ameliorant has become prominent. In Hawaii, calcium deficiency has been found to occur to a significant extent in the last few years. Visual symptoms of calcium deficiency are by no means rare in British Guiana and the Foliar calcium index becomes of very considerable interest.

In plant cane the critical calcium index has been tentatively placed at 0.16—0.17% Ca : it is possible that further work will place the index somewhat lower than this. It is more difficult to determine the calcium index accurately because of the beneficial effects of calcium-containing materials which are not directly connected with calcium nutrition.

The occurrence of calcium deficiency symptoms in the field has been associated with a calcium index of below 0.09% Ca and sometimes as low as 0. 06%Ca. A calcium index of 0.11 to 0.14% Ca has been of frequent occurrence in normal estate fields yielding up to 50 tons of cane/acre. However the index has very often been considerably higher than this at certain periods during growth.

Age has only a very small effect on the calcium index, the following mean values being obtained.

TABLE IV

Age	Foliar calcium index(% Ca)	Number of calcium analytical determinations on which Foliar index is based
12 weeks	0.210	625
20 weeks	0.202	1134
26 weeks	0.196	1080

There is evidence that the calcium index is affected to quite a considerable extent by excessive rainfall and to some extent by defective rainfall. The effect of rainfall during the four weeks preceding sampling is depicted graphically in Fig. 6.

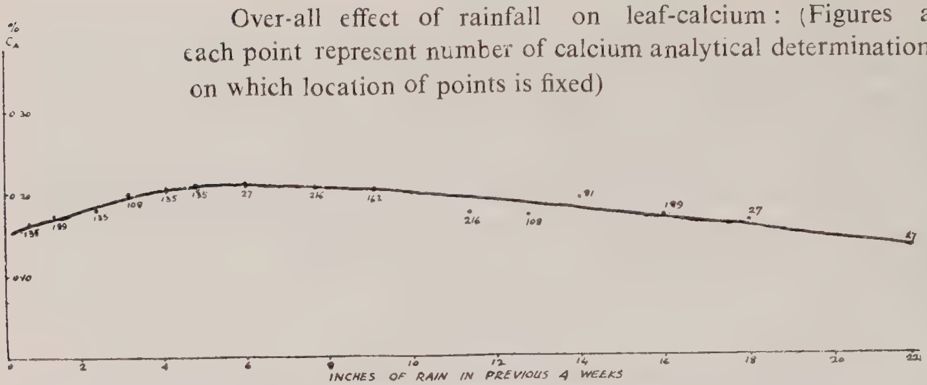
Over-all effect of rainfall on leaf-calcium: (Figures at each point represent number of calcium analytical determinations on which location of points is fixed)

Fig. 6. Effect of rainfall on calcium content

It will be seen that extremely wet weather is most conducive to calcium deficiency: indeed as mentioned previously acute symptoms may appear quite suddenly in cane that was previously growing well. This is due to the low mobility of calcium in the tissues and the consequent necessity of having adequate continuous uptake.

The factors involved in the uptake of calcium from the soil are by no means fully elucidated : cane from fields which have received as much as 6 tons/acre of ground limestone sometimes shows a very low calcium index. Sulphate of ammonia often greatly facilitates calcium uptake.

MAGNESIUM

This element is almost invariably adequate and, rarely, somewhat excessive in amount in British Guiana soils. A few cases have occurred where the application of fairly large potash dressings in the absence of adequate nitrogen applications has resulted in an induced magnesium deficiency. Deficiency symptoms of magnesium appear when the foliar magnesium index is 0.04-0.05% Mg and the critical level for magnesium is probably about 0.08-0.10% Mg. Excellent yields have been obtained with a magnesium index up to 0.30% Mg. Frequently where the magnesium index is high it is accompanied by a low potassium or calcium index and with the correction of the latter the magnesium index falls into the normal range.

MICRO-NUTRIENTS

The foliar indices for the micro-nutrients have been tentatively fixed as a result of nutrient culture work (Evans 1955).

Although of little economic importance micro-nutrients affect the growth of sugarcane in British Guiana in the following manner :—

(*a*) excessive accumulation of iron and or manganese under acid soil conditions and defective drainage.

(*b*) seasonal deficiency of boron of rare occurrence under heavy rainfall conditions.

(*c*) rare cases of molybdenum deficiency in very acid soils of poor structure and low calcium status.

(*d*) aluminium toxicity on pegassy soils overlying bauxitic clays.

The following are the approximate normal, deficiency, and excess levels of the micro-nutrients in the foliar tissue.

TABLE V

Element	Normal range parts per million (parts in dry matter)	Approximate deficiency level (PPM)	Suspected Toxicity levels(PPM)
Manganese	40—250	<25	>400
Iron	40—100	5	>200
Copper	5—15	<4	—
Zinc	20—100	<10	—
Boron	10— 40	<4	—
Molybdenum	0.08—0.80	<0.04—0.05	—

SUMMARY AND CONCLUSIONS

Results presented elsewhere indicate that foliar analysis is a reliable technique for the assessment of mineral status. The material considered here demonstrates that other variables-rainfall and age in particular under British Guiana conditions must be taken into consideration in interpreting the analytical values.

As the investigations proceed and more data become available for statistical treatment, it is believed that a more detailed quantitative assay of foliar analysis will become possible.

REFERENCES

Most of the literature cited has been referred to in a recent paper by H. Evans (Tropical Agriculture, October, 1955).

DISCUSSION

In reply to a question by Dr. Raheja as to the existence of a nitrogen gradient between the leaf sheath and blade, Dr. Evans said that there was an actual movement of nutrients from the storage tissues to the growing parts. Later Mr. Mohan Rao gave his experience of Andhra in which he pointed out that 2-2.5 percentage nitrogen at the fourth month stage was optimum and that it differed from Dr. Evan's value for British Guiana conditions. He also pointed out that under water-logged and drought conditions leaf nitrogen sometimes showed optimal values though yield was affected and as such leaf nitrogen was of limited utility as an index; he wondered if fractions of nitrogen would be more indicative and wanted elucidation from Dr. Evans on this point. Dr. Evans replied that uptake of nitrogen and phosphate was affected by water-logging as very little soil remained in the root zone and this depressed root growth. Specific information was, however, available on the role of nitrogen fractions as indicators of nutrient status.

Dr. Mangelsdorf presented the following two papers in the absence of the authors. These were discussed together.

Paper

CROP LOGGING

WHAT DO WE KNOW ABOUT IT ?

W.W.G. Moir

American Factors, Limited, Hawaii

Hardly a gathering of agricultural workers takes place in the cane sugar industry today without someone discussing the subject of "crop logging" and making claims for his or his co-workers findings. Analyzing many of these claims of the past and present, one realizes that definitions, background of work, conditions of testing, weather, time of year, variety of cane and many more factors are large influences in the reliability of the data and its significance to the claims made.

Probably the largest single factor in reliability is the representativeness of the sample collected for the condition being crop logged. This representativeness not only applies to the number of samples taken but also the part of the cane stool used. This latter point is influenced by all the growth habits and pattern of life at various ages of growth and also by the effect of weather, nutrition balances and cultural practices affecting these.

Yes, we have much to learn from the cane plant itself before we can lay down such "wonderful" methods of control as we have been promised and are being given day by day. By this I do not mean to belittle the value of what has been done. It just is not complete and much of the interpretation is far from correct.

In Hawaii we have known for well over 30 years that cane plants were greatly affected in the uptake of certain nutrients by various combinations of plant foods or the elimination of various elements. In those early days experiments were laid out to cover some of these combinations but since statistical methods were not developed at that time to evaluate the results, the experiments soon went into disrepute. Even today with very wonderful factorial experiments and newer methods of analysis we are still far short of proper evaluation.

When foliar methods of analysis and other rapid chemical methods of plant tissue analysis came into use in our Hawaiian industry through the work of Hance, Doi, Yuen and Borden at the H.S.P.A. Experiment Station in the late nineteen thirties, again we saw the same effects of elements on each other. The critical levels established by these workers were from limited data but fairly well showed that there were great possibilities in a study of this nature.

Several years later Dr. Clements was asked by Dr. Lyon, the Director of the Station, to collaborate with the Station on this problem. A review of the timing of these developments will be found recorded in the Planters' Record on the Nutritional Seminar held in September 1954. As a result of much controversy on the problem and to cover questions not being answered by the Clement's method or any other, the American Factors, Ltd., and six of their plantations—Lihue, Kekaha, Grove Farm, Oahu, Pioneer and Olaa—started in 1951 a huge coordinated experiment in cooperation with the Experiment Station to compare methods. This experiment covers two varieties of cane (37-1933 and 44-3098), three levels of nitrogen (0, 150, 300), three levels of potash (0,200, 400), three ages of harvest (18, 21 and 24 months), two times of planting (spring and fall, or early and late), and two methods of tissue analysis (stalk vs. sheath and blade) in both primary and sucker growth.

The harvesting data from the spring and fall plant for 18, 21 and 24 months have been summarized but only the spring plant data for crop logging by the two methods has been partially summarized. The logging data is coming in for the ratoon crops on these experiments and the first ratoon harvesting will be made shortly. It will be quite some time before all data can be statistically interpreted.

Some very clear-cut conclusions can be drawn from the crop log data as studied for the spring plant. The fall plant and ratoon data hurriedly run over by spot checking shows that the same conclusions can be made from them. However, it must be reported here before we enumerate the conclusions that sample representativeness of conditions being investigated must be good. Reliability of the data representing differences between treatments is greater for the stalk data than for the sheath-blade data. To be certain that the small differences shown in sheath-blade data are true differences and not just chance, one should double or treble the number of samples usually secured. This therefore becomes a problem of cost. However, this alone is not the only disadvantage to sheath-blade data. Long before the crop has reached maturity, in our 24-month cropping cycle, differences between levels of nitrogen in leaves of plants from plots of different treatment have narrowed down to practically the same level. It is doubtful if ten times the number of samples at these periods after 15 months would prove the differences statistically significant.

In the case of stalk analysis for total nitrogen in these same treatments we see clear-cut differences through to 24 months of age. We find great effects of the higher applications of nitrogen on the decrease of both phosphates and potash in the same tissue—reaching their greatest effect in the period around 6-8 months or just when the "boom stage" of growth is starting. These effects are not detrimental to yields when the levels of these two plant foods in the stalk still remain at high levels. However, in soil types of low availability of phosphate and potash, at certain times of the year, and in certain varieties of cane, the level to which these foods are lowered brings the amounts to seriously low figures.

Throughout the logging of this experiment, weight figures for various parts of the stalks sampled (primaries and suckers) have shown some exceedingly striking effects of time of year besides age of cane. The analysis of suckers have shown different levels of plant food content indicating ability to get food more easily even though produced long after the heavier fertilizer applications have been made. In the various parts of this large test the suckers were on the average 8-10 months younger in age, yet on most plantations in the test, the entire sucker stalk weighed more than the primary stalk at harvest time at 24 months.

Without going into much detail, because much has still to be done on these data, we would like to point out that most figures crop loggists have been talking about are percent figures on either the dry or wet basis. Most comment has completely ignored the weight of tissue produced. We find the Clement's method does use the green weight of leaf sheath sample but it is not too often referred to. The time of year effect shows markedly in these data but again numbers and size of stalks per foot of row are not evaluated along with this. They too are important figures in the understanding of proper nutrition and are definitely related to final yield.

In the study of stalk analysis comparing the basal portion of the stalk with the 8-10 joint (8-10 leaves down from the last visible dewlap) we find the 8-10 data most reliable for determining if there is proper nutrition at the time of the sample. This section of the plant however, maintains these levels at the expense of every other part of the plant. Where then should one look to see if levels of plant food content in the plant are dropping and be forewarned of any danger ? The data so far indicates that the basal joints are the "warehouse" from which the rest of the plant draws. Possibly if we had root analysis we would find they are being depleted by the basal joints.

The rates of depletion of the primary plant foods in this basal portion related to age and time of year should be able to guide the farmer in his fertilization after 6 or 8 months of age. Commenting on fertilization prior to this, one can say it is guided by all kinds of observations and knowledge secured long before crop logging is performed on the growing crop in Hawaii. Leaf analysis, as performed in British Guiana and the West Indies, may indicate things to do but most of us in Hawaii realize only too well the effect of weather (time of year) on such data and have no way of truly evaluating the effect of temperature, sunlight, and moisture on this part of the cane plant. We have heard recently that other foreign areas have come to the same conclusion as we have.

Another look into the "crystal ball" of data being amassed shows the ratoon figures as being on different levels and we shall have to determine whether these are time factors or depletion trends.

In conclusion, the data from our experiment, although far from being fully analysed, indicates that stalk analysis shows greater reliability, wider and longer lasting differences due to treatment than sheath-blade methods, large effects of nitrogen on potash and phosphate content, time of year effects on weights of parts being analysed (this is not entirely tied up with moisture), and that the same level of analysis at one plantation as at another may result in double the yield per acre. We must still find out more about the peculiarities of the cane plant and its reactions to treatment. A further study of the development and expansion of leaf area per acre and the subsequent increased weight to various parts of the plant might answer some of our problems. The tying in of this with the time of year effect (March to June) should give us the answer to maximum production. A study of data from Age of Harvest Experiments started and finished at various times of the year indicates for Hawaii that if more acres of cane, at ages of 8 to 12 months, are scheduled for the period March through June, the greatest yield will be obtained per unit of time. Studying reliable crop log data in relation to this will give us a sound method of crop control. However, one last word of warning—be certain the sample is truly representative of the condition.

Paper

STATUS OF CROP CONTROL IN HAWAII

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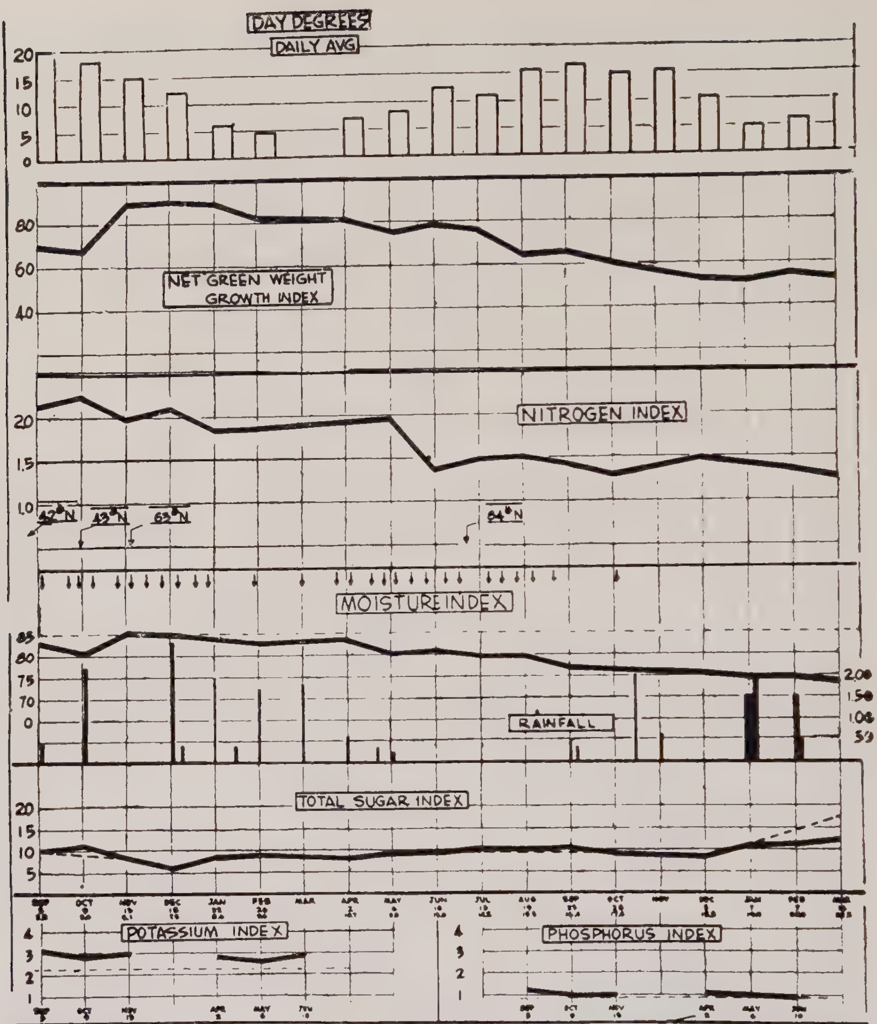
Crop control and crop logging for sugarcane in Hawaii began in 1938 when Dr. Harry F. Clements, Plant Physiologist of the University of Hawaii, and Dr. Harold L. Lyon, Director of the Experiment Station, HSPA, set up a co-operative project to study the relationship of plant composition to the fertilizer needs of the cane plant. At that time, the pineapple industry had introduced the principle of adjusting the fertilization of pineapples on the basis of field records and plant information. It was believed that if the composition of the cane plant could serve as a "quantitative index of its fertilizer requirements," it would be a big step forward in the scientific approach to cane fertilization.

Experimental plots were set up at the Waipio and Kailua Substations of the Experiment Station, HSPA. Facilities were provided at the University of Hawaii for making plant analyses. The Waipio Station was in an irrigated area with very bright, warm days: Kailua was unirrigated in an area of fairly heavy rainfall. Accurate meteorological records were kept and growth measurements were made. When the cane had reached the age of about seven months, sample plants were harvested and chemical analyses of the various tissues were made. These included moisture content, carbohydrates, nitrogen, phosphorus and potassium. From the data thus accumulated, a system of crop control, called "crop logging", was developed based upon "running indices of fundamental processes and factors." (4).

The primary index, or the total sugar content of the young leaf sheaths (Nos. 3,4,5 and 6) are used to reflect the balance between photosynthetic production and utilization by the plant (7). When the growth is below normal, this index rises. When the growth is excessive, this index drops. The index is used as a guide in fertilization, irrigation and other crop management practices.

The moisture index is taken as the moisture content on a green-weight basis of the elongating cane sheaths (5). The nitrogen index is the nitrogen content



CROP YEAR...1949		HARVEST DATA	FERTILIZATION–IRRIGATION
FIELD........97	STARTED 5-10-47	TC/A 89.37 BRIX 21.29	PLAN 210 #N 0 #P_2O_5 0 #K_2O
ACRES......316	STAND 6 MOS GOOD	TS/A 14.7 POL 19.54	ACTUAL 232 #N 0 #P_2O_5 0 K_2O
CYCLE......PLANT	HARVESTED 3/17-4/1/49	TC/TS 6.30 PURITY 91.78	AGE AT 1st N 2.25 MOS
VARIETY 32-8560	AGE 22.5	TCPAM 3.976	AGE AT LAST N 13.75 MOS
ELEV....775'-950'	TRASH % 18.31	TSPAM .631	DATE FIRST IRRIG 4-29-47
SOIL TYPE...RESI		TDD/TS 67.41	TOTAL NO. ROUNDS 36.35 TOTAL RAIN 41.46
M.E. RANGE 258-320			INTVL LAST 3 IRRIG ...16, 16, 52

Fig. 1. A typical crop log chart from an irrigated plantation

on a dry-weight basis of the elongating cane blades (6). Leaf punches from these blades are usually taken for analysis. The potassium index is the potassium content of the elongating cane sheaths expressed on a sugar-free dry-weight basis. The phosphorus index is the phosphorus content of the leaf sheaths expressed on a sugar-free dry-weight basis. In using the crop log, samples are taken every 35 days and the results of the analyses of the tissues are plotted on a running graph as shown in Fig 1.

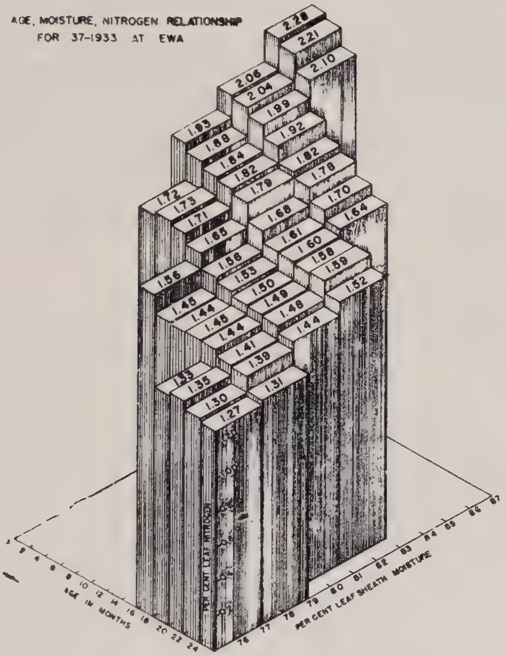


Fig. 2. A three-dimensional graph showing relationships between age, moisture and nitrogen.

Most of the cane grown in Hawaii is harvested when it is approximately two years of age. In applying crop-logging procedures to cane production, great emphasis is placed upon the way the cane is fertilized and irrigated during the first six months (8). The cane has to be about three months of age before it can be sampled. The first analyses should show that the primary index is below the 10 percent line, the moisture index above 85 percent, the nitrogen index at or above two percent, the potassium index at or above 2.25 percent, and the phosphorus index at or above 0.08 percent. About two-thirds of all added nitrogen is applied during this period. Generally speaking, moisture, potassium and nitrogen begin dropping during the period when the crop is six to 10 months of age. If the potassium index stays above 2.25, no further additions are made. Nitrogen applications for the second season are based upon clalculations involving the amount of nitrogen that has been applied, the age of the crop and the nitrogen index. Many other interesting relationships are involved in the use of the crop log. They are discussed adequately in the scientific papers referred to in the foregoing discussions.

By 1948, four plantations were using the Clements crop-logging technique for the fertilization and ripening of sugar cane. All experienced improved results over the practices they had been using. In 1951, the Department of Agronomy, in cooperation with the four plantations involved, began a statistical analysis and study of six or more years of crop-logging experience. Some of the results of these analysis are presented in Figs. 2 to 7.

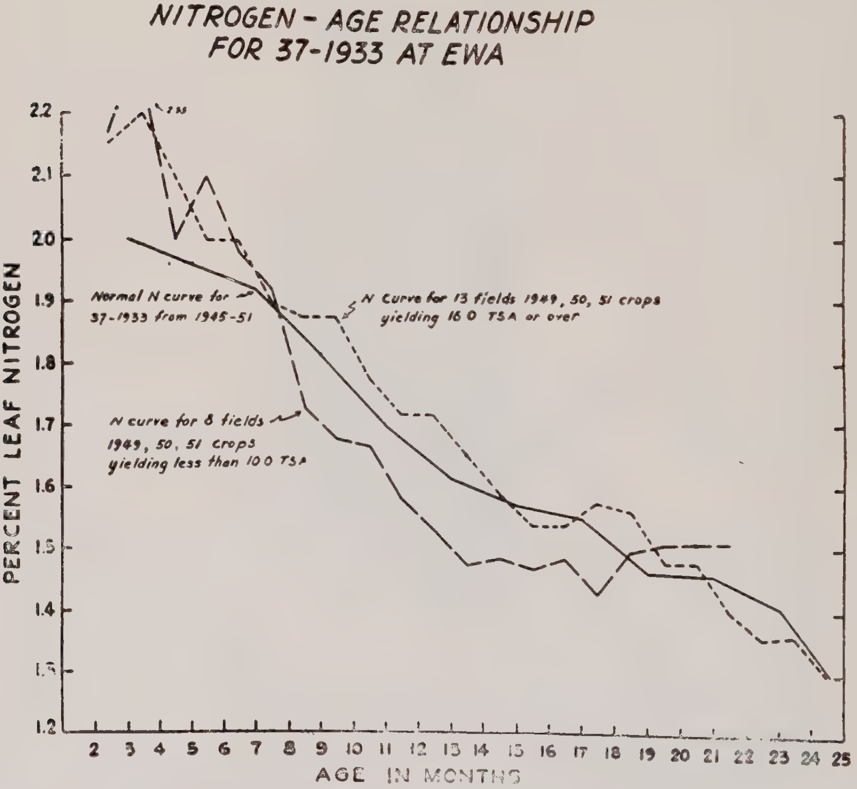


Fig. 3. The relationship of the percentage leaf nitrogen during the "boom" stage to field yields

The data in Fig. 2 show that the level of leaf nitrogen is dependent upon the age of the plant and the moisture status of the leaf sheath. The data show the necessity of evaluating moisture and age effects in the interpretation of the crop log. High leaf nitrogen is always associated with high sheath moisture and as one drops, the other also decreases.

The graphs in Figure 3 show quite clearly that maximum yields are obtained when the nitrogen content of the leaves is maintained at a high level during the "boom stage" of the cane plant. Although there was little difference between the leaf-nitrogen values for the higher-yielding and lower-yielding crops up to eight months of age and after 15 months, the higher-yielding fields showed more nitrogen in the leaf during the 8 to 15 month period. In other words, when the crop is growing rapidly, its nutrient requirements are high.

The effect of climate on leaf nitrogen is well illustrated in Figure 4 which shows that the nitrogen content increases with elevation at Kohala. Not only are the temperatures at the higher elevations lower, but there is also less sunshine, due to cloudiness. Somewhat similar effects are indicated in Figure 5 where the

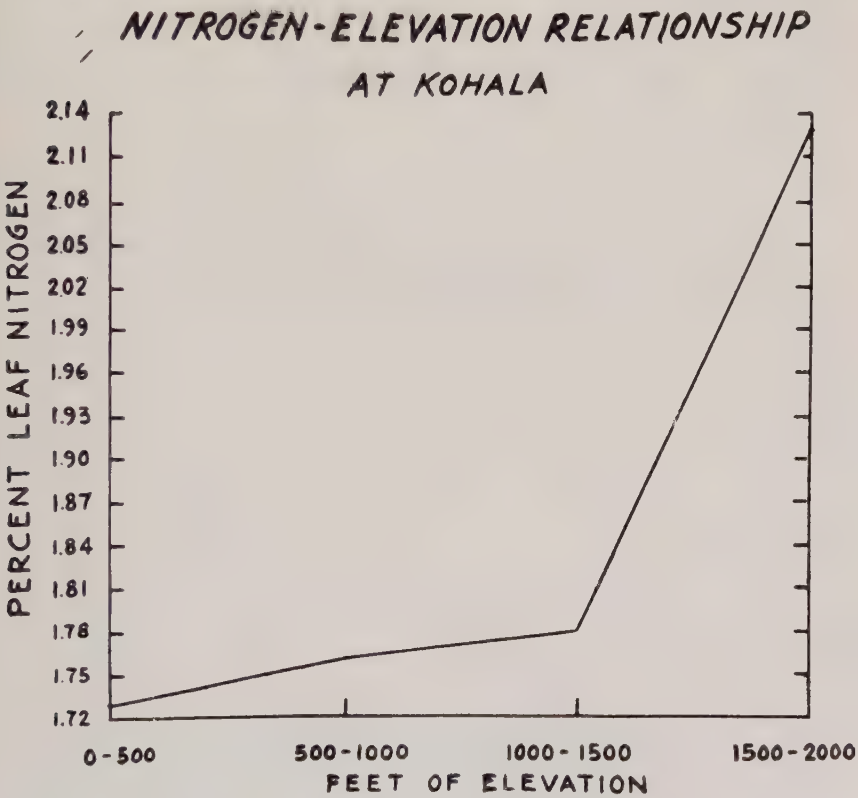


Fig. 4. The relation of climate to leaf nitrogen

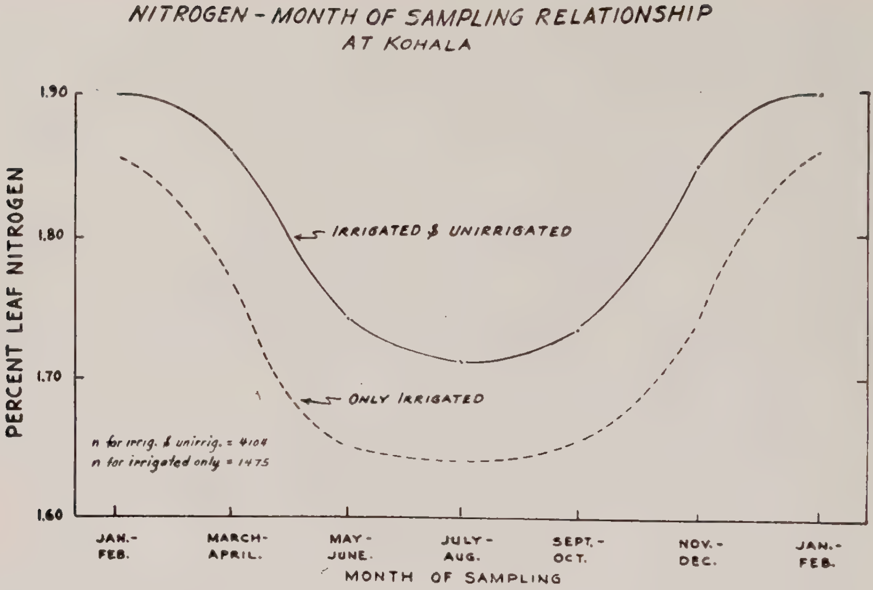


Fig. 5. The relation of the month of sampling to leaf nitrogen

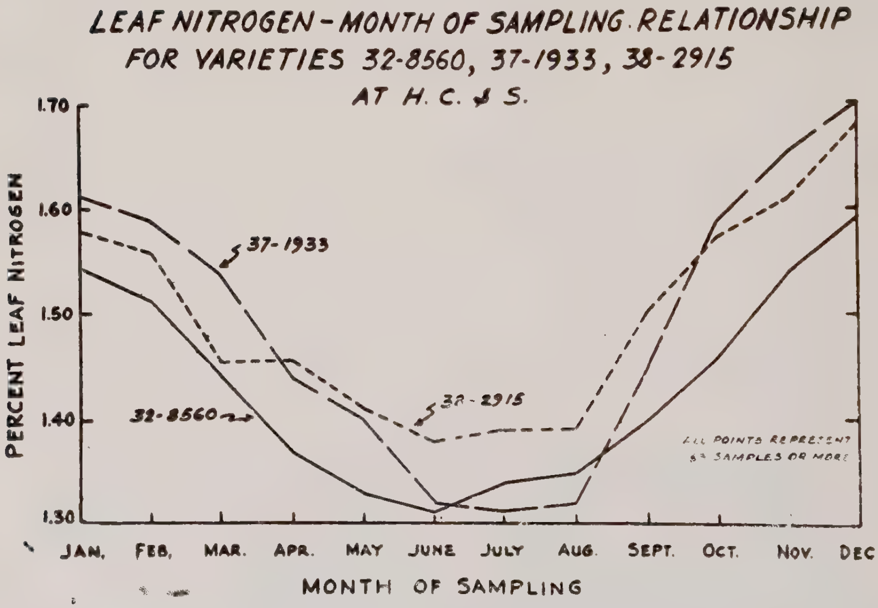


Fig. 6. The effect of variety on leaf nitrogen

lef-nitrogen levels in the summer months of May through October are considerably lower than at other times of the year. Lower nitrogen values during the summer months are experienced with various varieties as shown in Figure 6. These graphs also point out that there are varietal differences in plant composition although the relationships between composition and time of year are about the same for all three varieties. Sheath-potassium values show similar relationships to leaf nitrogen.

The data in Figure 7 show the relationship of leaf-sheath potassium to sheath moisture and age of plant. Here it is seen that low sheath moisture is always accompanied by low potassium values. This is similar to the sheath moisture-nitrogen effects shown in Figure 2. Moreover, at a given moisture level, as the age of the plant increases, the potassium values are higher.

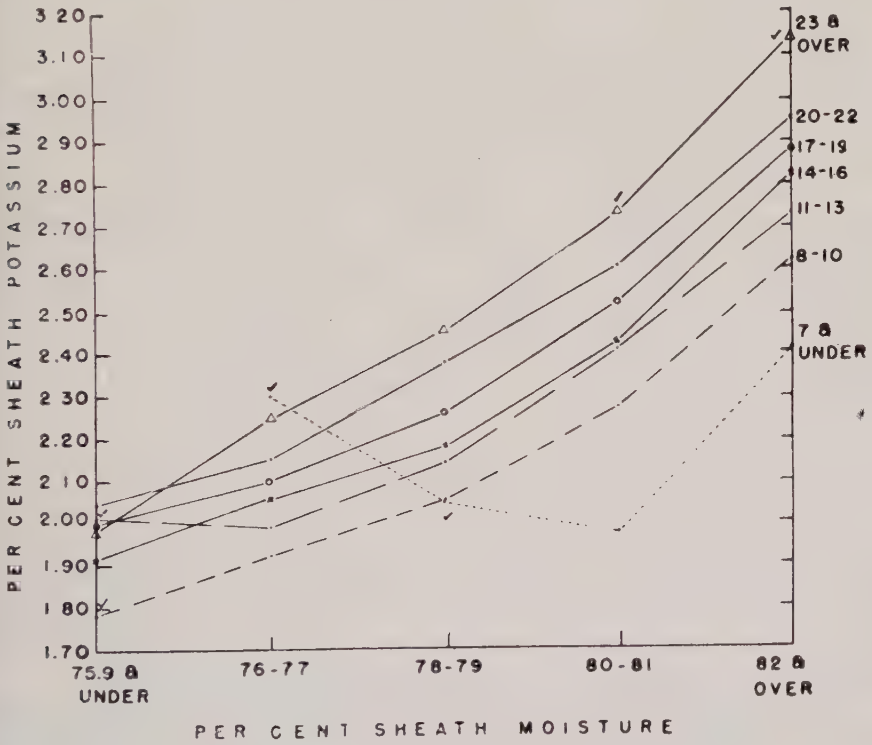


Fig. 7. The relation of sheath moisture and age to sheath potassium

These results point out the necessity of considering age, variety, moisture content of the leaf sheath and climate in interpreting crop-log data. They indicate the difficulties involved in trying to set a critical limit for plant tissues under varying conditions. They also show that good yields can be obtained if nutrient levels and moisture within the plant are kept high during the early growth of the plant.

LIMITATIONS OF INDEX TISSUES

The Department of Physiology and Biochemistry of the Experiment Station, HSPA, in 1947 began an intensive fundamental study of the nitrogen nutrition of the cane plant. These studies included in the use of N_{15}, or heavy nitrogen, for determining how the plant utilizes nitrogen and also the growing of cane under controlled conditions in special greenhouses. The purpose of these investigations was to obtain a much clearer picture of the nitrogen problems with the hope that many of the puzzling relationships associating-fertilizer response with plant composition would be clarified. It was particularly important to find out if the effect of different ecological conditions on the nitrogen index could be clarified.

In 1950, the Experiment Station began crop logging most of the Grade A experiments. The Station also interested other plantations of the industry in the use of crop-logging techniques, realizing that improvements in procedures would be forthcoming as further research solved the existing deficiencies.

Several limitations of these index tissues showed up as crop logging became more widely used under the different ecological conditions in Hawaii. This was particularly true with the leaf-sheath phosphorus and the leaf nitrogen. The leaf-sheath potash, moisture and sugars gave more satisfactory results.

Experiences with the use of leaf nitrogen in the field and greenhouse have indicated several weaknesses in the use of this index tissue in crop-logging techniques. For example, the variations in composition that occur under different ecological conditions pose problems of interpretation to the sugarcane grower. The grower would like to know what critical limits exist for his cane area so that he can carry on an economic utilization program that will keep his crop within the optimum limit of composition for good growth. The results in Fig. 2 show that leaf nitrogen varies with both age and moisture. The curve in Figure 4 points out that nitrogen values increase with decreasing temperatures. The data in Figure 5 indicate that the level of leaf nitrogen depends upon the time of year the plant is sampled. Figure 6 demonstrates that varieties differ in the level of leaf nitrogen at the same month of sampling. Field observations also have shown that additions of nitrogen fertilizers to the cane plant result in very little response in the leaf-nitrogen values. If the nitrogen curve has been declining, fertilization may retard the crop but rarely results in an increase in leaf nitrogen. On the other hand, a climatic change with no nitrogen additions may cause an increase in leaf nitrogen.

These varying effects are not peculiar to the Hawaiian industry. Similar effects were observed in Jamaica by Innes and Chinloy (11). They found the potassium values to be the most reliable and the nitrogen the least. They urge caution in the interpretation of nitrogen values. They place plots in every field and apply differential amounts of nitrogen fertilizer. The relative response in leaf-nitrogen values during the first four months of growth is used as a basis for fertilizing the field with additional nitrogen at the end of four months.

Halais (10) of Mauritius reports experiences similar to those of the Jamaica scientists. He finds that the use of three "micro-plots" with differential nitrogen treatments placed in each field gives satisfactory information if the leaves are sampled during the second and third months following the nitrogen application. The relative response in leaf nitrogen is noted.

Results from replicated phosphate fertilizer tests on Hawaiian plantations, which have given very significant differences in yields, have not shown generally significant differences in the leaf-sheath phosphorus. Moreover, there has been no constant correlation between field responses and the phosphorus content of the sheath. These experiences have been responsible for shifting the Experiment Station's research activities to soil phosphorus and stalk phosphorus.

NEW RESEARCHES ON PLANT ANALYSES AND CANE NUTRITION

The fluctuating leaf-nitrogen values and the insensitivity of leaf nitrogen to fertilizer additions caused the Experiment Station, HSPA, to analyse the problem critically and to search for more reliable index tissues. The resulting researches brought out some interesting facts (2, 3).

1. *Newly-added nitrogen does not concentrate in young tissue.* Nitrogen absorption studies with N_{15} have shown that the youngest leaves do not receive the largest amount of newly-added nitrogen. Leaves 4-6 received the greatest quantities. This is shown in Table I.

TABLE I

ABSORPTION OF N_{15} BY CANE LEAVES

Leaf No.	Total N percent	N_{15} Milligram percent
0 — 3	1.42	66
4 — 6	1.85	124
7 — 9	1.75	70
10 —11	1.50	35

Apparently nitrogen accumulates in those parts of the plant where there is a metabolic demand and not necessarily where a nutritional deficiency is shown by total analysis.

2. *Leaf-punch nitrogen varies under controlled climatic conditions.* Results from air-conditioned greenhouses have confirmed field observations on the effect of temperature on leaf nitrogen. The curves in Figure 8 point out that leaf-nitrogen values rise with a decrease in air temperatures and fall with a lowering of root temperatures. These data emphasize the difficulties associated with establishing a critical nitrogen level, based on leaf values.

3. *Stalk tissues more sensitive than leaf for evaluating nitrogen.* When nitrogen analyses, both total and alchohol-soluble, were made of various parts of the cane plant, it was observed that the stalk, rather than the leaves, was a much more sensitive indicator of the nitrogen nutrition of the plant. This fact

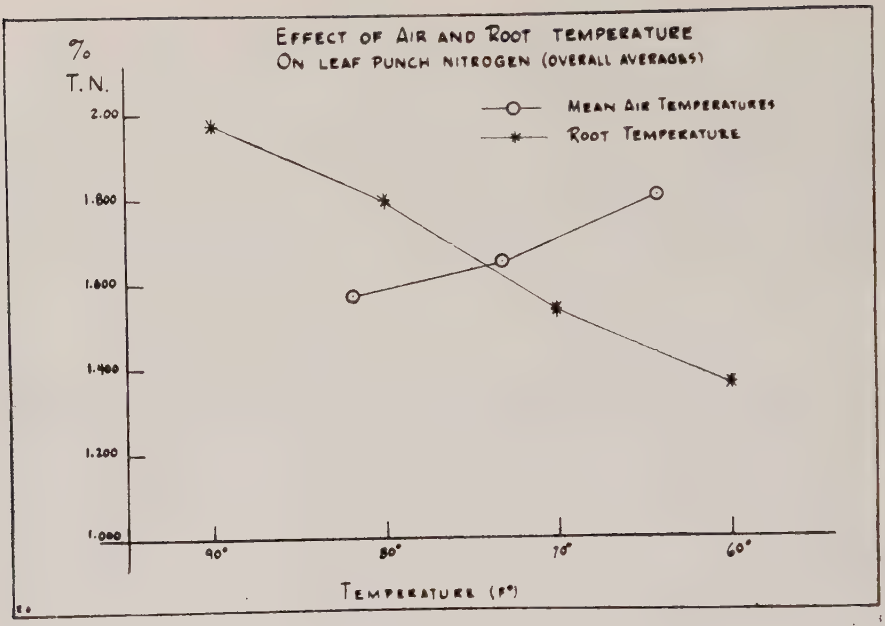


Fig. 8. The effect of temperature on leaf nitrogen values

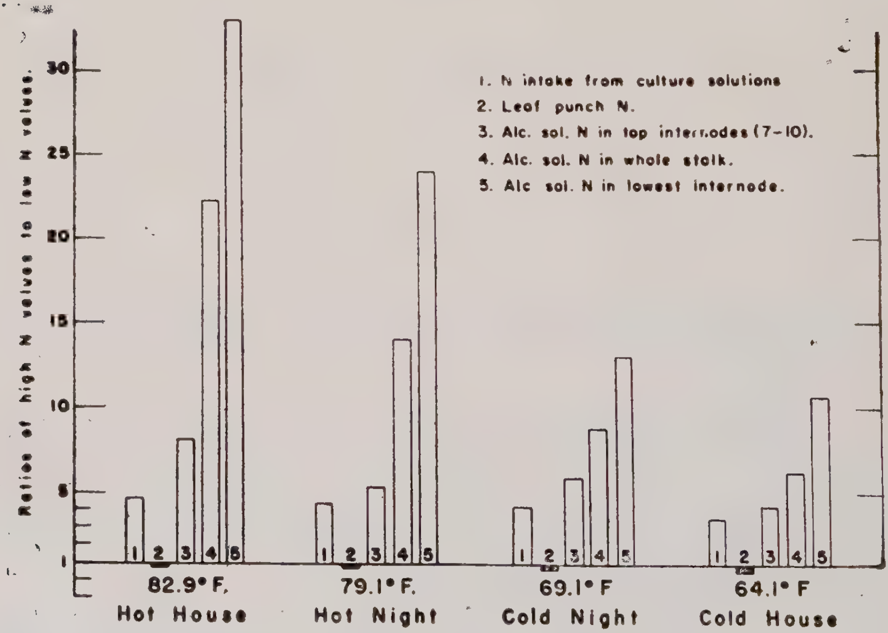


Fig. 9. A comparison of the relative absorption of nitrogen by cane plants under controlled climatic conditions as evidenced by the content of leaf and stalk-nitrogen

is well illustrated in Figure 9. Cane plants were grown in culture solutions at two levels of nitrogen. The high nitrogen solutions contained five times more nitrogen than the low ones. The data in Figure 9 for the hot house show that the plants absorbed five times more nitrogen from the high-nitrogen solutions. Under all four climatic conditions, the leaf nitrogen of the plants growing in the low-nitrogen solution contained the most nitrogen. The ratio high N/low N is less than one. In this experiment, the leaf nitrogen was correlated negatively with nitrogen absorption by the plant. However, in all cases, the stalk-nitrogen ratios were greatly in favour of the high-nitrogen solutions. These data, along with many others, have suggested that the stalk is a more sensitive and reliable index tissue than the leaf for evaluating the nitrogen nutrition of the plant.

4. *Field experiments show greater sensitivity of stalk tissues.* The relative sensitivity of various tissues is shown rather clearly by the data from field experiments in Figure 10. In this graph, the nitrogen content of the various tissues is plotted as percentage of the mean values for all analyses at the 0, 150- and 300-pound levels of nitrogen and for the 6-, 8-, 10-, 12-, 15- and 18- month samplings of the crop. Each point is the mean of 144 analyses. It is observed that the leaf-punch nitrogen (LPN) over this 12-month period only changed about nine percent

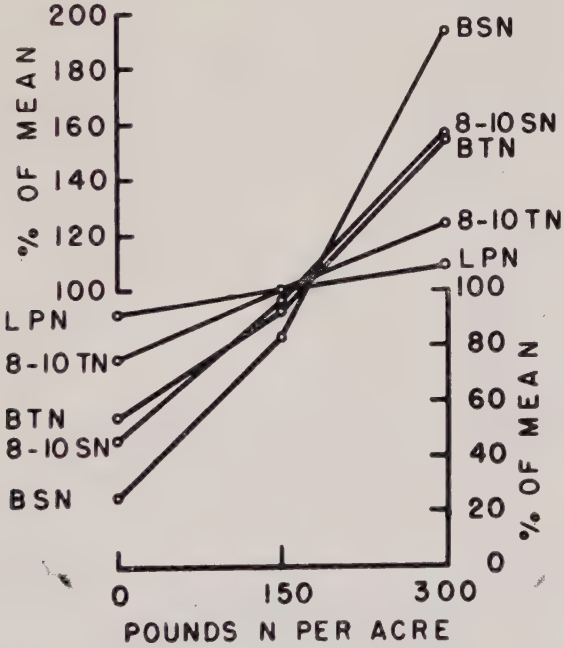


Fig. 10. The relative sensitivity of leaf (LPN), 8—10 internodes, 8—10 and basal internodes (B) portions of the cane plant to applied nitrogen. LPN=leaf-punch nitrogen ; TN=total nitrogen ; SN=alcohol-soluble nitrogen.

for the 150-pound application of nitrogen, whereas the basal, alcohol-soluble nitrogen (BSN) changed almost 100 percent. It should be noted that the 8-10 internodes are more sensitive than the leaf and the basal internodes more sensitive than the 8-10.

5. *Field experiments show greater reliability of stalk tissues.* Experimental data from replicated field experiments have provided interesting comparisons between leaf and stalk-nitrogen analyses. An example of such a comparison is given in Figure 11. There are several significant points to be gleaned from these curves. First, it is obvious that the leaf nitrogen does not separate the three fertilizer treatments as markedly as the stalk nitrogen. For example, at six months of age the 300-pound application of nitrogen has a leaf-punch value only about four percent higher than the 150-pound treatment and 20 percent higher than the check. At the same age, the stalk nitrogen of the 300-pound treatment is 100 percent higher than the 150-pound plot and about 1900 percent higher than the check. Second, the stalk nitrogen of the unfertilized plot gives a constant base of comparison with nitrogen treatment whereas the leaf nitrogen does not. For example, the stalk nitrogen of the check plot is low and constant throughout the

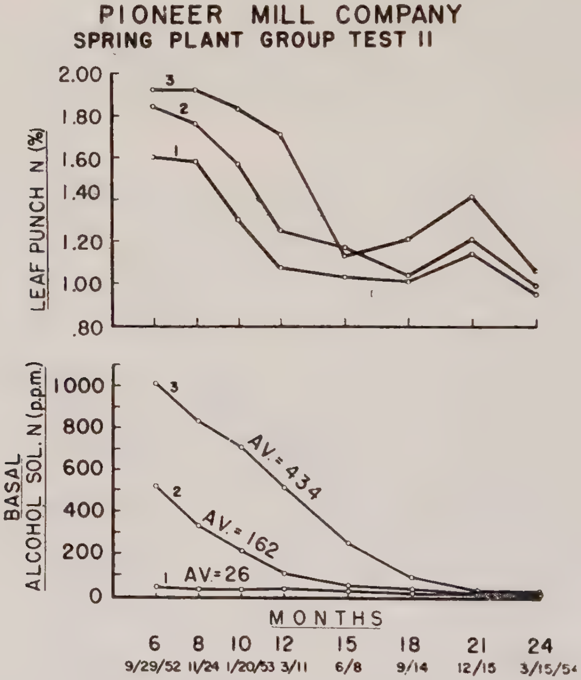


Fig. 11. A comparison of leaf and stalk nitrogen at different ages as affected by fertilization
Curve 1=no nitrogen added
Curve 2=150 pounds of N per acre
Curve 3=300 pounds of N per acre

6- to 24-month period. The leaf nitrogen of the check is not. This fact makes difficult the establishment of a critical nitrogen level for leaf nitrogen. Third, the stalk nitrogen for the 150- and 300-pound treatments decreases uniformly with age. Nitrogen from the 150-pound application was used up at about 15 months; the 300-pound application was not used up until about 21 months. On the other hand, the leaf-nitrogen values fluctuated considerably from six to 24 months, although the general trend for all treatments was downward. At 15 months, for example, leaf-punch values for the 300-pound treatment were lower than the 150-pound plot. There was a rise in all leaf-nitrogen values between 18 and 21 months. The change in the nitrogen content of the stalk tissues with age is the normal nitrogen-decay curve. The change of the leaf nitrogen with age is not only the usual nitrogen-decay curve but also a superimposed age effect. The net result of the two effects complicates the interpretation of leaf-nitrogen values. These comparisons show the more uniform, consistent, and plausible relationship between stalk nitrogen and treatment than between leaf nitrogen and fertilizer additions. Experience in Hawaii has shown, however, that in some instances the leaf-nitrogen values appear quite reliable; in other cases, they are difficult to explain. The large amount of data being accumulated suggest that in addition to the age effect, discrepancies with the leaf-nitrogen values may be associated with an insufficient number of samples taken for analysis.

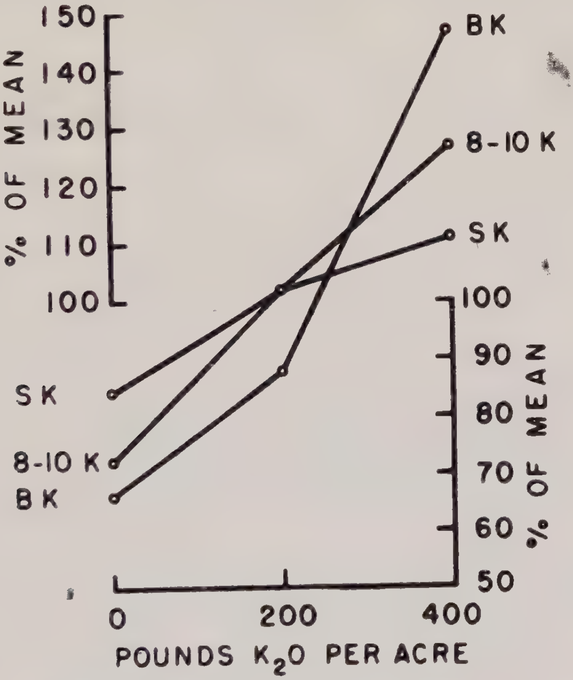


Fig. 12. The relative sensitivity of the leaf sheath (SK), 8—10 internodes (8—10 K) and basal internode (BK) to potash fertilization

Although the leaf-sheath potassium values are much more sensitive and reliable than the phosphorus analyses or the leaf-nitrogen content, nevertheless, the stalk analyses indicate a greater sensitivity. This fact is shown in Figure 12. It is noted in this graph that the slope of the sheath-potassium curve (SK) is much steeper than the leaf-punch-nitrogen curve (LPN) in Figure 10. However, the slopes of the 8-10 internodes and the basal internode (BK) curves are much steeper than SK. This indicates a greater sensitivity of the stalk analyses. This greater sensitivity means that smaller differences in potassium needs by the plant can be evaluated with considerable accuracy.

The absolute critical values of both nitrogen and potassium have not been established as yet. They are waiting final statistical analysis of replicated field experiments.

As previously mentioned, the leaf-sheath phosphorus has not proved to be reliable in majority of instances in Hawaii. Stalk analyses, however, suggest that either the 8-10 internodes or basal internode provide a more reliable index tissue than either the leaves or the leaf sheath. These comparisons are shown in Table II.

TABLE II

THE COMPOSITION OF VARIOUS PARTS OF THE CANE PLANT IN RELATION TO PHOSPHATE FERTILIZATION

OLAA EXP 101(a) FEBRUARY 3, 1954

200# P_2O_5 ADDED AUGUST 1953
PLANT CROP GAVE SIGNIFICANT YIELD GAIN

	BLADE 4		SHEATH 4		8 – 10 INTERNODE		BASAL INTERNODE	
	TOT.	INORG.	TOT.	INORG.	TOT.	INORG.	TOT.	INORG.
200# P_2O_5	2660*	780	970	590	530	270	480	250
X (NO P)	2480	680	850	520	290	140	310	140
DIFF.	180	100	120	70	240	130	170	110
LSD	160	-	-	-	80	60	30	60
DIFF./LSD	1.1	-	-	-	3.0	2.1	5.7	1.8
SIG	.05	NS	NS	NS	.01	.01	.01	.01

* P.P.M. P DRY WEIGHT

Highly significant stalk responses are observed in these results compared with no significant differences in the leaf-sheath phosphorus. Although these data come from only one experiment, similar results have been obtained with other phosphate tests. Data from 23 replicated field experiments on 10 plantations have indicated that 0.031 percent total phosphorus (dry weight basis) in the 8-10 internodes is the critical level. In all experiments, where the level was below this value, response from added phosphate was obtained. Clements (9) has endeavoured to overcome the inadequacies of the leaf-sheath phosphorus determination by correcting for moisture and sugars present.

SOIL ANALYSES FOR INTERPRETING FERTILIZER NEEDS

Any successful program of crop fertilization must take into consideration the fertility characteristics of the soils in which the plants are grown. One cannot place complete reliance on either plant or soil analyses alone. They must be used together as tools to help interpret fertilizer needs.

Emphasis on soil analyses in Hawaii has been the outgrowth of the deficiencies experienced with plant analyses for phosphorus. Moreover, the fixation of phosphorus by the soil makes it highly desirable to know the available phosphorus status at the start of the crop. One cannot always obtain responses from phosphorus is added to the surface of the soil once the crop is started.

Ayres and Hagihara (1) have analysed soil samples from the many phosphate experiments that have been carried out on the various sugar plantations in Hawaii. The results of their studies are shown in Figure 13. They have established the critical range of available soil phosphorus to be from 18 to 22 ppm. Only in four cases of the many reported was there a response from phosphate fertilization where the available phosphorus content of the soil (as determined by the modified Truog method) exceeded 20 ppm. However, there were phosphate responses from many soils that had less than 20 ppm. All the soils showing response at these lower levels of available phosphorus come from the Island of Kauai where the soils have twice the bulk density of those from the Island of Hawaii. When this difference in bulk density is considered, there is little discrepancy between the two areas.

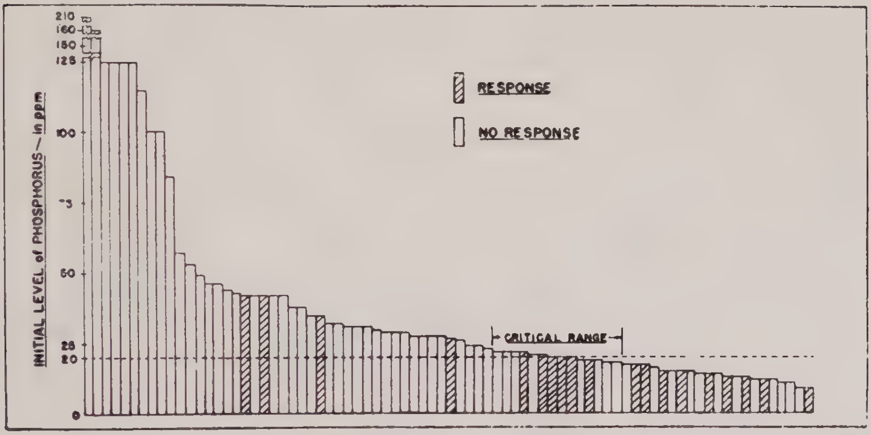


Fig. 13. The relationship of available soil phosphorus to response from applied phosphate

No explanation has been found as yet for the four analyses showing responses to phosphorus when the available phosphorus has exceeded 20 ppm. It is interesting to note that these four exceptions come from the same localized area. When the soil phosphorus data from field experiments are compared with the phosphorus from the 8-10 internodes, only two cases out of 25 are in disagreement.

The results of analyses from potash experiments are given in Figure 14. It is significant to point out the large increase in sugar production from potash applications on soils that have less than 75 ppm of exchangeable potassium. When the available potassium exceeds 100 ppm, the curve becomes essentially flat. There are only four instances of potash responses from soils that have more than 100 ppm of available potassium. The soils come from an area of low bulk densities. The "critical range", or "area of uncertain response", lies between 75 and 100 ppm for soils where the bulk density is about 2,000,000 pounds per acre foot.

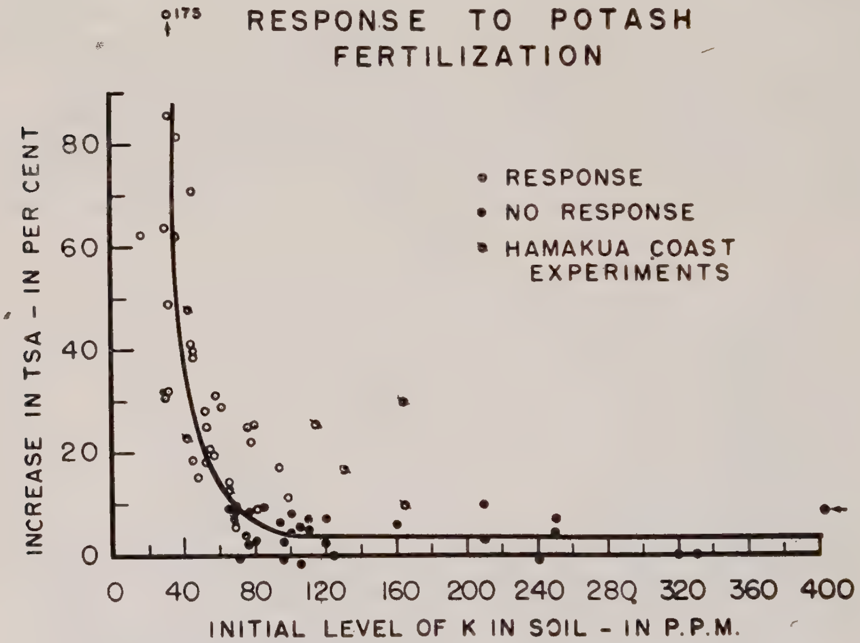


Fig. 14. The relationship of available soil potassium to response from applied potash

The few experiments on available calcium indicate that about 100 ppm is the critical level for exchangeable calcium. No response from added calcium has been obtained when the exchangeable calcium has been above 100 ppm. Experiments are in progress to check on the necessary levels for exchangeable magnesium.

ANALYSIS OF EXISTING INFORMATION AND METHODS OF APPROACH

It should be obvious from the foregoing discussion that there are at least two approaches to crop control in Hawaii. Both are based upon research in which the Experiment Station, HSPA, has had a part to a lesser or greater degree. System one, known as the Clements' crop log, has been used in the sugar industry for 10 or more years; system two, which has not been given a specified title, is relatively new.

It is interesting and significant to compare certain aspects of the two systems. This has been attempted in Table III. Actually, the major fundamental difference between the two systems lies in the method of approach to the problem of using the plant as an index of fertilizer requirements. In the first system, the young, growing parts of the plant are considered the key to plant analysis. The interrelationships of nutrients, water and sugar within these tissues are all important to successful growth. Certain levels at different ages must be maintained to achieve maximum yields. In order to maintain these levels, changes in the crop log must be detected soon enough to permit the application of fertilizer. Consequently, it is absolutely essential to sample the plant rather frequently to catch any changes that take place. Moreover, in this system nothing is known relative to nutrient levels in the soil. Therefore, since about 3½ leaves emerge every 35 days to give the necessary sampling material, this interval of time has been chosen for the frequency of sampling.

TABLE III

A COMPARISON OF CROP CONTROL SYSTEMS IN HAWAII

	System One	System Two
Research Basis	1. Minimum of replicated field experiments	1. Controlled greenhouse experiments
	2. Regression coefficients from field yields	2. Replicated field experiments
Tissues Used	1. Leaf for nitrogen	1. Stalk tissues for all values
	2. Leaf sheaths for other values	
Frequency of Sampling	1. Every 35 days until ripening control	1. Every 2 to 3 months during 6-12 or 15-month period and in preharvest studies
Interpreting Results	1. Emphasizes following changes in crop-log curves and compensating for age	1. Relates composition to critical values irrespective of age
Soils Information	1. No soil analyses considered	1. Available soil P, K and Ca considered along with plant analyses

The approach of the second system is somewhat different. Instead of trying to maintain a given balance of nutrients in the actively-growing parts of the plant, tissues were sought that exhibited (1) the highest sensitivity to composition changes as a result of fertilization, and (2) the smallest fluctuation in composition from changing climatic and other ecological conditions. All parts of the plant were investigated. A final analysis of the data indicated that the stalk tissues met these requirements. These stalk tissues actually represent the potential supply to the growing parts of the plant of those nutrients that the plants need. In other words using the stalk is sampling the supplying power of the plant to the actively growing tissues. Theoretically, such tissues should not be so subject to the individual fluctuations which are observed by frequent samplings of the rapidly growing portions. Moreover, one should expect that the stalk tissue need not be sampled frequently to serve as an accurate index tissue.

The use of stalk tissues permits an integration of soils and plant analyses for interpreting fertilizer needs. First, the soil is analysed to find out the potassium, calcium, magnesium and phosphorus status of the medium in which the cane will be growing. This gives a picture of the soil reservoir. Second, the stalk tissues, either the 8-10 or the basal internodes, are analysed for nitrogen potassium, calcium, magnesium, phosphorus, sugars and moisture. The two sets of information provide the tools that enable one to make fertilizer recommendations. The soil analysis is especially important for phosphorus since most of this nutrient must be applied in the furrow at planting time, before there are any stalks.

At the moment, the two systems are being compared on a field basis to find out if the stalk tissue is an improvement over the leaf and leaf-sheath tissues. If the stalk analyses prove more sensitive, more reliable and more economical than the use of leaf and sheath analyses, considerable progress will have been made in crop control in Hawaii.

CONCLUDING REMARKS

This paper has attempted to show as concisely as possible the various phases in the development and use of crop logging in Hawaii. Attention has been called to some of the deficiencies in the original concepts of crop logging. Researches have been discussed which attempt to improve crop control procedures. The present usage of crop control techniques in Hawaii may be summarized as follows :

1. Practically every plantation in Hawaii is using crop logging, either in its original form or some modification thereof. The Experiment Station has been recommending that the plantations continue using existing techniques until new researches prove definitely that certain basic changes should be made.

2. Plantation fields are being crop logged where both the stalk and leaf-sheath analyses are being compared.

3. Most replicated field fertilizer experiments are being logged, using both techniques to give comparable data. Emphasis is being placed on analyses during the boom stage.

4. Research is being continued by the Experiment Station to improve both plant and soil analyses for interpreting fertilizer requirements. Statistical analysis of a mass of important data from coordinated experiments on seven plantations is not completed as yet. The final results will shed considerable light on the future recommendations of the Station.

5. A majority of the plantations having phosphate problems are using soil analyses along with crop logging to help formulate fertilizer practices.

All of the accumulated evidence to date suggests that the future crop control program in Hawaii will include a combination of soil and plant analyses with less frequent samplings for plant composition.

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DISCUSSION

Dr. Evans remarked that in Hawaii foliar analysis is resorted to only for nitrogen and not for phosphorus and potash. The results presented in the paper showed little difference in leaf nitrogen between high and low yielding crops and he therefore failed to understand how the nitrogen requirement could be forecast by this method. The effect of temperature on leaf nitrogen and varietal differences with regard to amounts of NPK built up in tissue were other factors which appeared to render the procedure undependable. He further pointed out the inappropriateness of the analogy with Innes and Chinloy's work in Jamaica in this connection as their scheme of nitrogen application was different from that of the Hawaiian workers in that they applied differential amounts of additional nitrogen at closer intervals. Dr. Evans further said that the results showed no response to added phosphorus in most cases though its contents in dry matter was quite high and enquired as to form of phosphate fertilizer used.

In the absence of the author the following paper was taken as read.

Paper

THE APPLICATION OF FOLIAR DIAGNOSIS PROCEDURES TO COMMERCIAL SUGARCANE PRACTICES IN PUERTO RICO

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INTRODUCTION

The use of foliar diagnosis to determine whether the fertilizer requirements of sugarcane have been met has become a working reality. Like most scientific accomplishments, it is not a novel concept which developed almost overnight, but instead took many years to realize it. Nor is the technique or theory of foliar diagnosis for sugarcane a finished product. We do not yet know all of the answers. However, sufficient data and procedures have been evolved to make foliar diagnosis of sugarcane a practical tool of the agronomist in commercial cane culture rather than just a scientific laboratory affair.

With the cooperation of the Land Authority of Puerto Rico, the Agricultural Experiment Station, University of Puerto Rico, Rio Piedras, beginning in July 1953 applied the system of foliar diagnosis to the majority of their sugarcane lands except those of the Guanica area. The object of this paper is to tell briefly something of the procedure which has evolved from this cooperative project in foliar diagnosis and some of the benefits which have so far been derived from their use.

COMMERCIAL FOLIAR DIAGNOSIS PROCEDURE

The system of foliar diagnosis now practised in the non-irrigated cane areas of Puerto Rico is based on the taking of mainly one leaf sample only from the crop throughout the growing season for predicting fertilizer needs. Luce and Company, S. en C., Aguirre, use a system of foliar diagnosis in the southern part of Puerto Rico where cane is irrigated and where more than one cane-leaf sample is taken throughout the growth of the crop. This system is called crop logging.

Perhaps, the best way to acquaint you with how foliar diagnosis is practised commercially is to give you a brief condensed illustration of how foliar diagnosis is applied to a cane field.

(1) We received a report from the administrative office of the Land Authority telling us what fields are planted or cut, their size, the variety planted, and the fertilizer applied in the basic application (TableI).

TABLE I.

FOLIAR DIAGNOSIS WEEKLY FIELD INFORMATION SHEET

FOLIAR DIAGNOSIS PROGRAMME WEEKLY FIELD REPORT

Area: Loiza *Farm*: Virginia Date: November 1, 1953

Field		Acres	Harvest	Date of			Variety	Bags of fertilizers used per acre
No.	Crop			Planting	Cutting	Fertilizing		
32	G.C.	29	1956	10/24/53	—	10/23/53	M. 336	6 14-2-8
33	G.C.	18	1956	10/24/53	—	10/23/53	M. 336	6 14-2-8
38	G.C.	24	1956	10/26/53	—	10/25/53	B 37-161	6 14-2-8

Gran Cultura, 18 month cane

The amount of the basic fertilizer application was decided upon before hand from the results of past foliar diagnosis studies in that area plus economic and administrative considerations advanced by the grower. This basic application was applied just before planting for plant crops and no later than one month when possible after cutting for the ratoons.

(2) From this report a field sampling schedule is made up. The field will be sampled whenever possible at from 10 to 12 weeks after fertilizing the cane. Before going to the field the agronomist will check field maps to help decide how many cane-leaf samples will be needed from that field to best tell the fertilizer needs of the cane.

(3) In deciding how many samples to take from the cane field, the agronomist must consider the following points :

1. Size of the field
2. Number of the varieties growing in the field
3. Number of soil types occuring in the field
4. Differences in the topography of the field
5. Time of planting
6. Insect or disease damage
7. Poor growth in certain parts of the field
8. Evidence of chlorosis in parts of the field

9. Poor drainage in parts of the field.

(4) Arriving at the field with his sampling crew, usually 2 labourers, the agronomist will make any changes in his plans as needed, upon seeing that actual field conditions differ from the report of the field-map.

(5) For any one leaf-sample at least 5 canes are taken from the field. Leaf blades 4,5, and 6 are removed together with their leaf sheath. The leaf sheaths are placed in special moisture-proof bags and the leaf blades are placed in regular bags.

(6) Together with the leaf sample, the agronomist makes an entry into his field notebook on the following points :

1. Location as to area, farm, field, and section of field
2. Variety of cane sampled
3. Topography—whether field is level, rolling, or hilly
4. Heights of cane : approximated to nearest foot
5. Color of cane : dark green, light green, yellowish, chlorotic, etc.
6. Growth of cane : is its growth slow, regular, or accelerated for that variety in the same area
7. Evidence of disease or insect damage ; state extent and cause if identifiable
8. Condition of soil, texture, depth of soil for good root growth, evidence of hardpan or compaction, poor land preparation, shallow profile, rooting of cane poor or good, drainage if poor or excessive, and what recommendations can be made to improve the condition of the soil

(7) The chemical laboratory analyses the leaf blade samples for nitrogen, phosphorus, and potassium, and the leaf sheath for moisture. This report is then sent for interpretation for fertilizer recommendations (Table II).

TABLE II

SUGARCANE-LEAF ANALYSIS LABORATORY REPORT
FOLIAR DIAGNOSIS PROGRAMME LABORATORY REPORT
Date: February 3, 1954.

Sample No.	Nutrient content of leaf samples (dry weight basis) for Nitrogen	Phosphorus	Potassium	Moisture content of leaf sheath	Remarks
	Percent	Percent	Percent	Percent	
536	1.66	0.20	1.90	84.4	
537	1.31	0.18	1.92	83.2	
538	1.27	0.10	1.10	79.1	

(8) Using the chemist's report on the leaf samples plus the field notes

(Table III), the agronomist makes an interpretation of the fertilizer needs of the cane.

TABLE III

FIELD NOTES FROM FOLIAR DIAGNOSIS PROGRAMME

Leaf sample No.	Notes
536	Virginia farm, field 32, Colinas clay, Variety M. 336. Intense green colour. Good growth 3⅕ feet high. Topography level uniform with no evidence of poor drainage.
537	Virginia farm, field 33, Fajardo clay, Variety M. 336. Slight yellowish colour. Growth slower than field 32—2½ to 3 feet tall. Topography level and uniform. Soil more compact and heavy subsoil 6 to 8 inches below surface limiting root growth.
538	Virginia farm, field 38, Fajardo clay, Variety B. 37-161. Chlorotic cane along stream edge in area about 4 acres. Topography low with evidence of poor drainage. Growth poor—2 to 2½ feet. Soil wet and plastic. Root growth poor. Needs drainage ditches deepened.

He compares them with a set of standard values obtained from both field experiments and experience (Table IV) which is used as a guide.

TABLE IV

AVERAGE STANDARD LEAF-NUTRIENT VALUES FOR SUGARCANE IN PUERTO RICO IN GENERAL

Fertility status	Leaf nutrient content (dry weight basis)			Moisture status	Sheath moisture (green-weight basis)
	Nitrogen	Phosphorus	Potassium		
	Percent	Percent	Percent		Percent
vl—very low	below 1.00	below 0.10	below 1.00	very low	below 78.0
l—low	1.00-1.40	0.10-.15	1.00-1.50	low	78.0-80.0
sl—slightly low	1.40-1.50	.15-.18	1.50-1.65	normal	80.0-85.0
r—regular	1.50-2.00	.18-.25	1.65-2.00	high	above 85.0
h—high	2.00-2.50	.25-.30	2.00-3.00		
vh—very high	above 2.50	above .30	above 3.00		

If his basic fertilizer recommendation was good and the cane shows no further need for fertilizer, he will say so. If any further fertilizer is needed, he will indicate what formula and how much to apply. If other factors need correcting, he will also indicate that. Normally, if sampled at an age of 10-12 weeks, the recommendation for the field is ready within 10-14 days after sampling. A typical fertilizer recommendation sheet is given in Table V.

TABLE V

FERTILIZER RECOMMENDATIONS FOR VARIOUS CANE FIELDS BASED ON FOLIAR DIAGNOSIS

FOLIAR DIAGNOSIS FERTILIZER RECOMMENDATIONS REPORT

Area: Loiza *Farm*: Virginia *Date*: Feb. 5. 1954

Field No.	Soil	Variety; Crop	Nutrient content				Fertility status			Recommendations for second fertilizer application (per acre)
			N	P	K	H_2O	N	P	K	
32	Colinas clay	M.336 G.C.	1.66	0.20	1.90	84.4	r	r	r	O.K.
33	Fajardo clay	M.336 G.C.	1.31	0.18	1.92	83.2	l	r	r	400 pounds ammnoium sulphate (2 bags)
38	Fajardo clay	B-37-161G.C.	1.27	0.10	1.10	79.1	l	l	l	Correct drainage in field

BENEFITS OF FOLIAR DIAGNOSIS

At present the system of foliar diagnosis for sugarcane has not been in commercial operation long enough to give exact figures of what savings have been realized in fertilizers or how yields have been influenced. However, enough data have been collected from specific cases in the field to show how even at this early stage, with only one year in practice commercially, foliar diagnosis is proving of benefit to the sugarcane grower.

The main accomplishments to be credited to foliar diagnosis are :

1. Detection of fertilizer deficiencies
2. Detection of the use of excessive amounts of fertilizer
3. Detection of improper balance in sugarcane fertilizer application
4. Detection of factors other than fertility causing poor growing conditions in sugarcane.

Each accomplishment will be discussed separately with actual field samples to illustrate the point involved.

DETECTION OF FERTILIZER DEFICIENCIES

Because of the high costs and amount of time involved in performing fertilizer experiments with sugarcane, specific information is not available for all of the soils of Puerto Rico regarding their fertilizer requirements for sugarcane. In many instances, general fertilizer recommendations are made for large cane growing areas, because no information is available on particular needs of different soils in that area. By the use of foliar diagnosis, deficiency of a fertilizer element has been detected in areas not heretofore suspected of needing that fertilizer element. Examples of these are :

POTASH DEFICIENCIES

Deficiencies of potash were found in Lajas on non-irrigated cane grown on a Santa Isabel silty clay and in Humacao at Colonia Santa Teresa on a Via silty clay. The results are given in Table VI.

TABLE VI

POTASH DEFICIENCIES ON SUGARCANE AS REVEALED BY FOLIAR DIAGNOSIS

Area	Soil	Fertilizer applied pounds per acre of			Nutrient content of leaf sample (percent dry weight)			Yield of Available 96° sugar per acre	Sucrose percent cane
		N	P_2O_5	K_2O	N	P	K		
					%	%	%	Cwt.	%
Lajas[1]	Santa Isabel	300	360	0	2.30	.26	0.95	128	12.63
	Silty clay	300	360	240	2.36	.27	1.63	169	13.07
Humacao[2]	Via silty clay	300	300	0	1.30	.30	0.96	56	10.76
		300	300	300	1.22	.19	1.73	90	12.54

1. Gran Cultura 1950-52, B.34-104, Lajas Substation.
2. Second ratoon 1953-54, P.O.J. 2878, Colonia Santa Teresa, Eastern Sugars Associates.

It is interesting to note that on the Santa Isabela silty clay when receiving adequate irrigation, the cane did not show potash deficiencies, but under the drier conditions revealed a response to potash. At Humacao, the potash deficiency was severe enough to lower both cane tonnage and yields significantly. Other areas found to be low in potash by means of foliar diagnosis are portions of cane land at Central Rufina and areas in Fajardo and Loiza under Land Authority of Puerto Rico control.

PHOSPHORUS DEFICIENCIES

Although sugarcane in general has not shown a heavy demand for phosphorus fertilizers in Puerto Rico, there are soils and growing conditions occurring where phosphate fertilizers are needed for sugarcane in Puerto Rico. Foliar diagnosis has detected phosphorus deficient cane growing in Coto clay at Isabela. Yields increased when phosphates were applied. Low leaf phosphorus values have been obtained also in the Fajardo Area.

DETECTION OF THE USE OF EXCESSIVE AMOUNTS OF FERTILIZER

Fertilizers help give higher yields of sugarcane when needed, but only up to a certain limit, after this no economic benefit is realized and even harm may result from the use of excessive amounts of fertilizer. Foliar diagnosis has detected excessive use of fertilizer on commercial cane by virtue of extremely high leaf value due to a luxury consumption of the fertilizer element.

Example of this excessive usage are shown in Table VII for several soils and areas in the Island. This excessive usage gives no higher yields and may prove harmful by lowering sucrose as in the case of nitrogen.

TABLE VII

INDICATIONS OF EXCESS FERTILIZER APPLICATIONS FOR SUGARCANE AS REVEALED BY FOLIAR DIAGNOSIS

Area	Farm	Field	Soil	Variety	Crop[1]	Leaf nutrient content (percent dry weight)			Sheath moisture
						N	P	K	
Cambalache	Monte Grande	5	Toa silty clay loam	B41-227	G.C.1955	2.00	0.21	2.06	85.5
Plazuela	Los Matos	5	Bayamon silty clay loam	M. 336	G.C.1955	2.06	0.17	2.08	86.6
	Luisa	43	Toa silty clay loam	M. 336	G.C.1955	2.25	0.19	2.40	86.3
Average for high yields based on experimental data						1.75	0.20	1.83	82.5

[1] All received 1200 pounds of a 14-2-8 at time of planting.

DETECTION OF IMPROPER BALANCE IN FERTILIZER APPLICATION

The sugarcane plant requires a balanced diet of plant food; it cannot live on any one fertilizer element only. Although nitrogen fertilizer is the fertilizer material usually most needed in Puerto Rico, at times the amount used by the cane grower is far in excess of actual needs and this throws the entire plant out of nutritional balance.

Example of the harm done by use of sulphate of ammonia only for many years on cane is shown in Table VIII.

TABLE VIII

IMPROPER BALANCE IN FERTILIZER APPLICATION AS DETECTED BY FOLIAR DIAGNOSIS

Area	Farm	Field No.	Soil	Variety	Crop[1]	Leaf nutrient content (percent dry weight) N	P	K	Sheath moisture
Fajardo	Fe	43	Via clay loam	M.336	G.C.1955	2.04	0.14	1.20	82.2
Loiza	San Isidro	63	Coloso silty clay	M.336	G.R.1955	1.68	0.15	0.54	80.0
Toa	Bambu	39	Coloso clay	M.336	G.C.1955	2.30	0.18	1.44	82.0
	San Antonio	17	Almirante clay	B37-161	R. 55	1.79	0.12	0.88	78.4

[1] All received 1200 lbs. of ammonium sulphate (20% N) only.

We see here that leaf-nitrogen values are very high but there are very low leaf-phosphorus and potassium values. The high nitrogen applications have depressed the potassium and phosphorus intake in the cane plant. This in turn causes a condition which leads to high tonnage but lower sucrose values in the cane.

DETECTION OF FACTORS OTHER THAN FERTILITY CAUSING POOR CANE GROWTH

Many sugarcane growers believe that fertilizers contain the magic power to solve all of their problems in the field. Unfortunately, this is not true. Where needed, fertilizers are most important for growing sugarcane. But they do not cure improper preparation of the field, excessive weeds, disease and insect damage, use of poor varieties, poor drainage, soil compaction, hardpan, low pH, and lack of moisture. No fertilizer manufacturer gives this guarantee on his bag of fertilizer. Yet many, many times, fertilizer is used to cover up for the other faults in the proper growing of sugarcane. Through the proper use of foliar diagnosis, we have been able to detect many of these causes for poor cane growth other than those due to a lack of fertilizer, and we have made recommendations for their correction.

Examples of how foliar diagnosis was of value in detecting these conditions of poor growth are given in Table IX.

TABLE IX

CONDITIONS OF POOR GROWTH CAUSED OTHER THAN BY LACK OF FERTILITY REVEALED BY FOLIAR DIAGNOSIS TECHNIQUE

Area	Variety	Crop	Soil	Leaf nutrient content dry weight basis N	P	K	Sheath moisture	Limiting conditions indicated by field notes or lab. test
A: Toa	B37-161	Primavera 55	Martin Penia sandy clay loam	1.30	0.08	0.92	78.8	Poor drainage
B: Fajardo	B37-161	G.C. 55	Cialitos clay	1.46	0.12	0.92	78.9	Soil pH 4.4 poor drainage
C: Fajardo	M. 336	G.C. 55	Fajardo clay.	1.68	0.12	1.08	80.8	Only 4 inches soil then rocky parent material.

Here we see cane whose leaf samples have low nutrient and moisture values despite the fact that they received 6 bags (1200 pounds of 14-2-8) plus 2 bags (400 pounds) of sulphate of ammonia and no shortage of moisture was present. Our field notes help give the answer. In case A, poor drainage caused poor rooting which did not allow the roots to take in the plant food. In case B, a very low pH coupled with poor drainage caused extremely poor root growth. In case C on a sloping field the soil was only from 4 to 6 inches deep below which parent rock was found. The roots did not have enough room to grow and the soil dried out very rapidly because of its shallow profile. The recommendations needed here in these cases were not for fertilizer but other measures instead. To be sure, a few more bags of fertilizer might stimulate more root growth near the surface of the soil, but proper correction of the limiting conditions would allow higher yields without using extra heavy rates of fertilizer.

If for no other reason than the fact that it keeps the sugarcane grower in closer contact with actual field conditions of his sugarcane as it is growing, foliar diagnosis has already proven its value in the growing of sugarcane.

CONCLUSION

It would be wrong to leave you with the conclusion that foliar diagnosis for sugarcane is so highly perfected that it can solve all sugarcane fertilizer problems. Nor would it be fair to let you assume that it is an easy fool-proof procedure that anyone without any experience may use. For this is not so. For foliar diagnosis to function properly, trained personnel is essential—not only the chemists, but also the agronomists who do the field sampling and make the interpretations. Foliar diagnosis will be of value to the sugarcane grower of Puerto Rico so long as it remains a dynamic procedure which combines the field observations with laboratory data. It will fail us when it becomes a mere routine procedure performed by a clerk filling out recommendations from a chart.

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In the absence of the author the following paper was taken as read.

Paper

CORRELATION AT DIFFERENT AGES BETWEEN NITROGEN, GREEN AND DRY-MATTER CONTENTS OF LEAVES, AND YIELD OF SUGARCANE GROWN IN SAND CULTURE

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INTRODUCTION

Sugarcane and nitrogen play important roles in the agricultural economy of the Commonwealth of Puerto Rico. In 1950-51, nearly 45 percent of the total land in crops was devoted to growing sugarcane and 10,501,396 tons of cane were produced with a value of $ 106,379,000. The total for 1953-54 was 10,879,000 tons with a value of about $104,000,000. About 100,000 tons of nitrogen-bearing materials were imported in 1949-50 at a cost of $4,000,000 ; this increased to 272,177 tons in 1950-51, and the amount imported was 213,914 tons in 1953-54, costing about $8,000,000.

Nitrogen imports doubled after 1949-50, while sugarcane production remained more or less constant. These figures imply an excessive application of nitrogen to sugarcane above that required for optimum growth. Data from two long-time experiments performed by the Soils Department of the Agricultural Experiment Station of the University of Puerto Rico, one in an acid soil in the humid area and one in a calcareous soil under irrigation in the arid area have demonstrated that optimum yields of 12 consecutive crops of sugarcane, averaging 45 tons of cane per acre per crop, could be maintained with an annual application of 103 pounds of nitrogen per acre. Most farmers of Puerto Rico generally use two to three times that amount.

REVIEW OF THE LITERATURE

Clements (5, 6) in Hawaii, Bonnet (1), and Capo, et al (4), in Puerto Rico, Innes (8) in Jamaica, and Halais (7) in Mauritius have discussed leaf nitrogen as a suitable index for the control of fertilizer applied to sugarcane. Rouillard (10) proposed the vegetative index, or the weight of 20 sugarcane leaves of the third rank, with the sampling done during the summer months, January to April, at the age of 8 to 10 months for virgins and 5 to 7 months for ratoons.

OBJECTIVES

A suitable index such as is proposed in this paper would be of great assistance to farmers if it enabled them, early in the life of their sugarcane crops, to determine whether additional nitrogen applications would be beneficial. For they could then correct nitrogen deficiencies affecting growth, and this would ultimately lead to large reductions in nitrogen costs.

In this work the low and high levels of nitrogen were known before planting time, because inert sand instead of soil was used as a substratum. Data are presented on correlation studies between the nitrogen content, the green and dry weights of the leaves, and the yield of sugarcane as a means of predicting relative yields when the nitrogen levels in the growth medium varied from deficiency to excess.

EXPERIMENTAL PROCEDURE

Twenty-eight concrete pits, each about 0.00077 of an acre in area, 7 feet 9 inches long, 4 feet 4 inches wide, and from 1 foot 9 inches to 1 foot 11 inches deep, provided with a drainage outlet, were constructed on the floor of a greenhouse with glass and ventilators at the roof, and open at the sides as shown in Fig. 1. A 3-inch layer of 800 pounds of thoroughly washed, non-calcareous, 1/2-inch, river gravel was placed on the bottom of each pit; this was covered with 3,000 pounds of acid quartz sand.

The seven randomized treatments used were replicated four times and consisted of variable-unit concentrations of nitrogen, while the other nutrient elements were kept constant at maximum rates. The unit concentration used per pit was 0.03 pound of N, 0.015 pound of P_2O_5, and 0.015 pound of K_2O.

The nitrogen was applied to the sand in the ratio of 90 parts of nitrate to 10 parts of ammonia, as proposed by Trealease and Trealease (11) for a medium around pH 6.0. The ammonia was added as ammonium sulphate, and the nitrate as tetrahydrated calcium nitrate. Seven different levels of nitrogen were studied, each containing 9 units of P_2O_5 and 13 units of K_2O (Table IV). The concentrations in parts per million of the other elements were ; Ca 165 ; S 124; Mg 33 ; Fe 13 ; Mn 1.07 ; Zn 0.83; Co 0.27 ; B 0.13.

Sugarcane seeds of the M. 336 variety were disinfected before planting by immersion in hot water at 52°C for 20 minutes, and were then cut crosswise in one-eye node sections. These sections were planted on September 25, 1952, at a rate of one for each of four holes uniformly spaced in each pit, and were also germinated in a separate sand-bed to supply material for replanting. The plants were irrigated with rainwater when needed, after the drainage had been poured back.

Fig. 1. Sugarcane variety M. 336, nine months old just before arrowing, grown in sand culture.

Composite samples of the third, fourth, fifth and sixth leaves, including blades and veins, were taken monthly at various growth intervals starting at 3 and ending at 15 months. The green weight of each of these samples was taken, and they were then prepared and analyzed for moisture and nitrogen by a method reported elsewhere (2,9).

Arrowing started at 13 months. The crop was harvested on December 25, 1953, at the age of 15 months. Weight of cane, sugar, trash, and roots were recorded per treatment and the cane juice was analysed for juice extraction and sugar content. The correlation between the nitrogen content, or the arc-tangent (3) of the nitrogen content of the sugarcane leaves, at the different monthly intervals, and the yield, or relative yield, of the cane were determined for the different nitrogen levels. The relative yields were based on percentages of the maximum yield. Similar correlations were also determined for the green and dry weights of the sugarcane leaves.

RESULTS AND DISCUSSION

The mean nitrogen contents and of the green and dry weights of sugarcane leaves at the various monthly intervals are reported in Tables I to III. The yields of cane, sugar, trash, and roots, the percentage of extracted sugar in the cane, and the least significant yield difference between mean treatments are reported for the various nitrogen treatments in Table IV. There were significant responses at the 1-percent level to nitrogen in the yields of cane, sugar, trash and roots.

The percentages of variation explained by correlations between nitrogen, green or dry wieghts of the third, fourth, fifth and sixth leaves of the cane, obtained at different ages of the cane, and yields are reported in Table V, and the coefficients of variability in Table VI. The significance of the correlation of the corresponding yield estimate was about the same for all ages between arc-tan nitrogen (3) and relative yield, and between nitrogen percentage and yield of cane ; so also were the corresponding coefficients of variability. This similarity in the pattern of significance of correlations may be attributed to the low values of leaf nitrogen percentage (range 0.95 to 3.10, Table I) where the tangent curve is more or less linear.

The significance of correlation and coefficients of variability was about the same between green weight or dry weight and yield of cane, but a higher correlation was obtained by the green weight at 6 months and by the dry weight at 15.

TABLE I

MEAN NITROGEN CONTENTS AT DIFFERENT CROP AGES OF THE LEAVES OF SUGARCANE VARIETY M. 336 WHEN GROWN IN SAND CULTURES AT DIFFERENT NITROGEN LEVELS

Units[1] of N per pit	Percentage of nitrogen (N) in months indicated												
	3	4	5	6	7	8	9	10	11	12	13	14	15
1.0	2.93	1.33	1.28	1.16	1.09	1.27	1.43	1.43	1.40	1.12	1.30	1.01	1.18
2.5	3.07	1.95	1.74	1.52	1.16	1.22	1.51	1.49	1.37	1.14	1.39	1.19	1.15
4.0	2.96	2.03	1.88	1.54	1.27	1.39	1.45	1.31	1.39	0.99	1.11	0.95	1.07
5.5	2.92	1.91	1.90	1.82	1.53	1.43	1.71	1.51	1.38	1.11	1.25	1.08	1.03
7.0	3.03	1.99	1.98	1.69	1.70	1.60	1.78	1.61	1.39	1.20	1.32	1.19	1.31
8.5	3.00	2.12	2.05	1.92	1.69	1.75	1.79	1.64	1.53	1.25	1.39	1.29	1.20
10.0	3.10	2.14	2.00	1.91	1.82	1.80	1.92	1.68	1.65	1.35	1.47	1.28	1.29

[1] One unit is equal to 0.03 lb. N.

TABLE II

MEAN GREEN WEIGHTS AT DIFFERENT CROP AGES OF THE THIRD, FOURTH, FIFTH AND SIXTH LEAVES OF SUGAR CANE VARIETY M. 336 WHEN GROWN IN SAND CULTURES AT DIFFERENT NITROGEN LEVELS

Units[1] of N per pit	Green weight in grams in months indicated												
	3	4	5	6	7	8	9	10	11	12	13	14	15
1.0	148	178	184	178	213	196	171	194	110	164	120	100	105
2.5	124	171	200	202	250	212	186	211	108	199	116	115	129
4.0	130	174	205	219	235	233	233	227	130	208	146	104	123
5.5	121	184	202	224	270	257	269	236	146	212	135	122	127
7.0	136	190	201	223	288	249	292	281	136	245	151	153	165
8.5	104	155	211	230	312	286	300	292	126	239	174	152	139
10.0	144	172	207	219	315	267	295	284	137	253	199	136	166

TABLE III

MEAN DRY WEIGHTS AT DIFFERENT CROP AGES OF THE THIRD, FOURTH, FIFTH AND SIXTH LEAVES OF SUGARCANE VARIETY M. 336 WHEN GROWN IN THE SAND CULTURES AT DIFFERENT NITROGEN LEVELS

Units[1] of N per pit	Dry weight in grams in months indicated												
	3	4	5	6	7	8	9	10	11	12	13	14	15
1.0	29	44	49	50	62	62	51	48	31	45	34	29	32
2.5	25	41	49	54	73	66	55	52	30	55	32	34	38
4.0	27	42	49	59	68	72	69	59	36	61	43	31	36
5.5	24	45	51	60	74	76	76	60	41	65	39	36	39
7.0	28	47	51	60	78	73	79	70	37	69	43	43	48
8.5	22	39	51	60	82	79	81	73	35	67	49	44	45
10.0	30	41	50	59	85	74	78	70	38	70	55	39	49

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[1] One unit is equal to 0.03 lb. N.

TABLE IV

MEAN CANE, SUGAR, TRASH, AND ROOT YIELD, AND PERCENTAGE SUGAR CONTENT OF SUGARCANE VARIETY M. 336, WITH LEAST SIGNIFICANT DIFFERENCES BETWEEN TREATMENT MEANS, WHEN GROWN IN SAND CULTURES AT DIFFERENT NITROGEN LEVELS.

Treatment No.	Units per pit of N	P_2O_5	K_2O	Mean crop yield in tons per acre Cane	Sugar	Trash	Roots	Percentage of sugar in cane
1	1.0	9	13	20.0	2.1	5.8	4.0	10.3
2	2.5	9	13	27.8	3.1	8.1	5.9	11.2
3	4.0	9	13	50.1	5.9	11.9	8.4	11.9
4	5.5	9	13	62.8	8.3	13.8	7.5	13.1
5	7.0	9	13	73.8	10.0	16.1	8.1	13.7
6	8.5	9	13	81.3	11.0	19.0	7.7	13.5
7	10.0	9	13	83.1	10.7	19.0	7.3	12.9
L.S.D. between treatment means :								
1-percent point				13.2	1.4	4.0	3.3	1.9
5-percent point				9.6	1.0	2.9	2.4	1.4

One unit equals 0.03 lb. of N and 0.015 lb. of P_2O_5 or K_2O.

TABLE V

PERCENTAGE OF VARIATION EXPLAINED BY CORRELATION OF THE YIELD ESTIMATES OBTAINED AT DIFFERENT AGES OF THE CANE

Cane age (months)	Leaf arc-tan N and relative yield	Leaf N percentage and cane yield	Green-weight and cane yield	Dry-weight and cane yield
3	1	3	0	0
4	38††	36††	3	8
5	32††	28††	11	4
6	32††	26††	28††	22†
7	65††	61††	39††	37††
8	52††	50††	56††	28††
9	33††	33††	79††	80††
10	14†	15†	25††	24††
11	8	8	16†	18†
12	8	10	38††	42††
13	0	0	46††	49††
14	23†	22†	14†	16†
15	4	4	11	16†

† Significance at 5 percent; †† significance at 1 percent.

TABLE VI

COEFFICIENTS OF VARIABILITY OF THE YIELD ESTIMATES OBTAINED AT DIFFERENT AGES OF THE CANE

Cane age (months)	Leaf arc-tan N and relative yield	Leaf N percentage and cane yield	Green-weight and cane yield	Dry-weight and cane yield
3	44	44	44	44
4	35	35	44	42
5	36	37	42	42
6	37	38	38	39
7	26	27	35	35
8	31	31	30	38
9	36	36	21	20
10	41	41	38	39
11	42	43	41	40
12	42	42	35	34
13	44	44	33	32
14	39	39	41	41
15	43	44	42	41

The correlation between leaf nitrogen percentage and cane yield was not significant at ages of 3, 11, 12, 13, and 15 months ; it was significant at the 5-percent level at 10 and 14 months, and at the 1-percent level at 4, 5, 6, 7, 8 and 9 months. The percentage of variation explained for the highest significant correlations between these values varied from 26 to 61, and the coefficients of variability from 27 to 38. The highest variation and the lowest coefficient of variability were obtained when the cane was 7 months old. The coefficient of correlation for 7 months was 0.78 for leaf nitrogen and cane yield and 0.81 for arc-tan nitrogen and relative yield and the regression equations obtained were :

Yield of cane in tons/acre = 63.021 (leaf N in percent)—35.26

Relative yield of cane = 3.567 (arc-tan N in percent)—136.32

The correlation between green weight and yield of cane was not significant at the ages of 3, 4, 5, and 15 months ; was significant at the 5-percent level at the ages of 11 and 14 months ; and significant at the 1-percent level at the ages of 6, 7, 8, 9, 10, 12 and 13 months. Similarly results were obtained with dry weight, except that the correlation at 6 and 15 months were significant at the 5-percent level. The percentages of variation explained for the highest significant correlations between green or dry weights and cane yields varied from 28 to 80 percent and the coefficients of variability between 20 and 39 percent. The highest variation explained and the lowest coefficient of variability were obtained when the cane was 9 months old.

The coefficient of correlation for 9 months was 0.89 for either green or dry weights and cane yield. The respective regression equations for green and dry weights were :

Yield of cane in tons/acre) =0.394 (green weight of leaf in grams)—41.24

Yield of cane in tons/acre =1.767 (dry weight of leaf in grams)—66.53

CONCLUSION

The above correlation analyses indicate that the percentage nitrogen content of the third, fourth, fifth and sixth leaves of sugarcane can be used as an index to predict the yield of cane almost as precisely as the arc-tangent of the nitrogen percentage.

The green and dry weights of these leaves can also be used to predict the yield.

The age of the plant must be taken into consideration for prediction of the yield. Correlation with nitrogen were significant at all ages between 4 to 10 months, and of green or dry weights between 6 to 14 months, for the M.336 cane variety grown in sand cultures at different nitrogen levels.

SUMMARY

Sugarcane variety M. 336 was grown in sand cultures in 28 pits under cover to study the effect of increasing levels of nitrogen on crop yield and the correlation between the nitrogen, the green-or dry-matter contents, and crop yield. Seven increments of nitrogen, replicated four times, were studied with other nutrients and water at optimum levels.

The yield in tons per acre varied as follows : cane, 20.0 to 83.1 ; sugar, 2.1 to 11.0 ; trash, 5.8 to 19.0 ; roots, 4.0 to 8.4.

The sugar in the cane varied from 10.3 to 13·7 percent when the crop was harvested at the age of 15 months. There were significant responses to nitrogen at the 1-percent level in the yields of cane, sugar, trash, and roots.

The nitrogen content of the third, fourth, fifth, and sixth leaves varied from 0.95 to 3.10 percent when the cane was between 3 and 15 months old; the green weight of these four leaves varied from 100 to 315 gms. and their dry weight from 22 to 85 gms.

Results indicate that nitrogen, and the green-or dry-matter contents of the cane leaves can be used to predict relative crop yields at specific crop ages. This is illustrated with three formulae derived from the data.

ACKNOWLEDGEMENT

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IRRIGATIONAL

In the absence of the author the following paper was taken as read.

Paper

COMPUTATION OF IRRIGATION REQUIREMENTS OF SUGARCANE FROM CLIMATIC DATA

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INTRODUCTION

There is an increasing need for improved irrigation efficiencies in many sugarcane producing areas. Water shortages frequently occur while large areas receive excessive irrigation supplies, thereby raising the water table and in many instances creating salinity and drainage problems.

In the Cul-de-Sac Plain in Haiti about 12,000 acres are irrigated from the Riviere Blanche system. Here the irrigation supply during dry months is adequate for about 4,000 acres. During the rainy season this same area is frequently over-irrigated resulting in poor drainage conditions in the lower portion of the water service area. Lack of adequate drainage combined with a high water table in the lower areas contribute in a large measure to problems of salinity. Much improvement in crop production can be had thru improving the knowledge of irrigation requirements for good yields of sugarcane as well as thru improving irrigation supplies. Studies necessary for improving irrigation supplies in turn require a good knowledge of crop irrigation requirements.

NEED FOR IMPROVED METHODS

Several methods are used in determining when to irrigate sugarcane and the amount of water to be applied. Most of these give more importance to the control of the irrigation interval than to controlling the irrigation efficiency or the amount of water delivered to the fields. Some of the more important methods include : growth measurements, soil moisture determinations, day degrees of temperature, tensiometers, nylon blocks, gypsum blocks and evaporation data.

In the United States several formulae have been developed for the transfer of irrigation requirements or consumptive use data from one area to another. These have been useful in the climatic conditions where they were developed. Fuhriman and Smith[1] measured the consumptive use of water by sugarcane in the south coastal area of Puerto Rico and found a good degree of correlation between water use and rate and stage of growth. It appears that if irrigation requirements at comparable stages of growth are related to evaporation, this fact forms the most practical means of transferring irrigation requirements and consumptive use data from one area to another. Use of this method is supported by Pruitt and Jensen[2] who compared consumptive use for four crops with evaporation as well as the Blaney-Criddle and Thornthwaite procedures. They found evaporation to be a superior means of transferring data and of determining when to irrigate.

In the use of the above mentioned methods of irrigation control improvement can be made by knowing the rate at which the cane is using water and by measuring quantities to the fields sufficient to fill the soil reservoir, making allowance for a reasonable efficiency.

For crops with well developed root systems permeating the crop root zone, the use of water and consequently crop growth are not influenced by moisture level in the soil as long as the moisture is above the permanent wilting point[3]. It seems logical to assume that sugarcane generally has a well developed root system. If the amount of readily available moisture that can be stored in the crop root zone and the rate at which the crop is using water are known then over-irrigation and waste of water can in many cases be materially reduced.

Data are available for the consumptive use of water by sugarcane planted late in March and harvested the following April at Aguirre in the south coastal area of Puerto Rico [1'4]. Consumptive use in inches is as follows :

Jan.	Feb.	Mar.	Apr.	May.	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
4.4	3.7	3.7	3.6	3.7	4.2	4.6	5.6	5.7	5.4	5.1	4.4

If the technician knows how much water sugarcane uses on the South Coast of Puerto Rico, does this information help him to know how much water is required in another area, say in India ? If evaporation data are available at both places the answer is definitely in the affirmative. If evaporation is not known then climatic data can be used in determining approximate rates of evapotranspiration potential.

FACTORS INFLUENCING EVAPOTRANSPIRATION POTENTIAL

Evaporation from a U.S. Weather Bureau pan or from a free water surface depends upon energy input, duration of energy input and the factors associated with the removal of evaporated or transpired water vapour. Energy input is best measured by temperature in °C or °F—32. The length of day provides a convenient index of energy input duration. The relationship between evapotranspiration potential and climate can be expressed mathematically by the equation :

$$e = c\ d\ (t-32) \quad \ldots \quad \ldots \quad \ldots \quad (1)$$

in which 'e' is the monthly evaporation in inches (evapotranspiration potential); 'c' is a climatic factor depending principally upon humidity ; 'd' is a monthly day-time coefficient; and 't' is the mean monthly temperature in °F. Values of 'd' are computed by relating monthly daytime hours for each month to an average value (a monthly percent of daytime hours of the year of eight and one third is equal to 1.00). Monthly daytime coefficients calculated for latitudes 5 to 35 north are presented in Table I.

TABLE I

MONTHLY DAYTIME COEFFICIENTS(d)

	North Lat. in Deg.						
Month	5	10	15	20	25	30	35
Jan.	1.01	0.98	0.96	0.93	0.91	0.88	0.85
Feb.	0.91	0.89	0.88	0.87	0.86	0.84	0.83
March	1.02	1.02	1.01	1.01	1.01	1.00	1.00
April	0.99	1.01	1.01	1.02	1.03	1.05	1.06
May	1.03	1.05	1.08	1.10	1.12	1.14	1.17
June	1.00	1.03	1.06	1.08	1.11	1.14	1.17
July	1.03	1.06	1.08	1.11	1.13	1.16	1.19

TABL I (Contd.)

August	1.03	1.05	1.06	1.08	1.09	1.11	1.12
Sept.	0.98	0.99	0.99	0.99	1.00	1.00	1.00
Oct.	1.02	1.00	0.99	0.98	0.97	0.96	0.94
Nov.	0.98	0.95	0.93	0.91	0.89	0.86	0.84
Dec.	1.00	0.97	0.95	0.92	0.89	0.86	0.82

Although wind movement has a minor effect, the climatic factor (c) influencing the removal of water vapour is a function principally of mean monthly relative humidity. By using climatic data the climatic factor (c) was evaluated as follows :

$$c=0.38-0.0038\ h \quad \dots \quad \dots \quad \dots \quad \dots \quad (2)$$

in which 'h' is the mean monthly relative humidity at noon

Equation (1)becomes :

$$e = d(0.38-0.0038\ h)\ (t-32) \quad .. \quad \dots \quad \dots \quad (3)$$

TRANSFER OF CONSUMPTIVE USE DATA

Consumptive use for sugarcane is assumed to vary, under differing climatic conditions, directly with the consumptive use potential. Expressed mathematically :

$$U = KE = \Sigma k\ e \quad \dots \quad \dots \quad \dots \quad (4)$$

in which U is the consumptive use of sugarcane in inches for the irrigation season or for a stated period ; E is the sum of the monthly values of evaporatio or consumptive use potential for the period ; K is an empirical coefficient derive from the consumptive use data from Puerto Rico; 'k' is the monthly consumptiv use coefficient ; and 'e' is the monthly consumptive use (evapotranspiration potential as previously defined. Monthly values of consumptive use coefficients (k) based on data from the south coastal area of Puerto Rico are given as follows

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
0.75	0.70	0.50	0.50	0.55	0.55	0.60	0.75	0.85	0.85	0.90	0.85

The annual or growing season value of "K" is 0.70 indicating that the consumptive use of water by sugarcane averages about 70 percent of evaporation from a U.S. Weather Bureav pan or about 70 percent of the evapotranspiration potential as computed from Equation (3).

Many technicians consider evaporation from a free water surface to be superior to Weather Bureau pan evaporation in the transfer of consumptive use. Use of a different means of measuring evaporation may require some revision of Equation (2)..

The procedures outlined above permit the computation of month by month consumptive use requirements of sugarcane for any set of climatic conditions. It is suggested that technicians working in areas where adequate climatic data are available check values computed by use of Equation (3) against measured evaporation and that the consumptive use for Puerto Rico be transferred to as many locations as possible and compared with field practices and other consumptive use data.

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In the absence of the author the following paper was taken as read.

Paper

METEOROLOGY, EVAPORATION AND THE WATER REQUIREMENTS OF SUGARCANE

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PART I

INTRODUCTION

Roots supply plants with the greater proportion of the water which they use during their lifetime, but roots can only extract water from a soil if the free energy of the water in the plant is greater than that in the soil in immediate contact with the roots. In each layer of soil there is therefore some minimum water concentration which corresponds to the maximum stress against which plants can extract water and is known empirically as the wilting point—equivalent to a moisture stress of 20-30 atmospheres. Under most field conditions the economic production of sugarcane is related to the level at which the soil moisture equivalent stresses are maintained and the cost of maintaining these levels. Where natural rainfall is insufficient, the problem becomes one of the relationship between growth (and ultimately, recoverable sugar yield) and soil moisture stress during the life of the crop, and how to control these stresses most economically.

The building up of moisture stress in the soil results, almost exclusively once drainage ceases, from the loss of water by transpiration and by evaporation through the soil surface, and under conditions of a continuous canopy, the latter is negligible as will be shown later. The quantitative evaluation of soil moisture losses occurring in the above manner can therefore be arrived at, either by computing accumulated evapotranspiration, or by obtaining an integrated measure of soil tension and evaluating this in terms of the mean moisture stress characteristic curves for the depth of soil reckoned to be affected. The former is essentially a simple water accounting proposition since the meteorological factors influencing the loss of water are very even over the area of single fields (and, for that matter, over much greater areas too) whereas the latter has to contend with the heterogeneity of the soil and root system in three dimensions as well as with the variation in the unsaturated permeability of the soil.

It is true that a degree of commercial control of irrigation is being currently practised by the application of the latter method. Nevertheless, if the evapotranspiration of the cane could be easily measured, it might yet prove a more practical way of controlling irrigation. It certainly would need very little capital investment nor would it require the frequent recording of a very large number of widely dispersed instruments. Baver has raised the subject with respect to cane (2). It is already being applied to tobacco (20).

THE METEOROLOGICAL APPROACH TO EVAPORATION AND TRANSPIRATION

The approach is not new, since the processes involve the utilization of solar energy and is not surprising, e.g., Dalton as early as in 1801-2 related evaporation from open water sources to some of the physical properties of the air which was receiving the water vapour (4) (5), and his equation was later used by numerous workers on the subject, including Penman (12) who has reviewed the subject.

The most empirical and the simplest correlations have been attempted with temperature. Thus Das (6) as early as 1933 attempted to define irrigation interval—a function principally of transpiration—in terms of the accumulated "day degrees" and the method was actually used for the control of commercial irrigation in sugarcane (7). Baver (1) showed that the evaporation from free water surfaces throughout the United States could be effectively correlated with a function of temperature (in°F), and Blaney and Criddle (3) related total evapotranspiration from an area to mean monthly temperature and day time hours. Thus, according to Blaney and Criddle—

$$U=KF=\Sigma kf \qquad \ldots (1)$$

where U=Consumptive use or evapotranspiration in any period
F=Sum of monthly consumptive use factors for the period
K=An empirical consumptive use coefficient (growing period)
k=Monthly consumptive use coefficient
f=Monthly consumptive use factor=$t(p/100)$
t=Mean monthly temperature, °F
p=Monthly percent of day time hours of the year

Thornthwaite (18) evolved a more complex relationship with air temperature based on the empirical observation that the logarithm of the monthly evapotranspiration in centimetres adjusted to a standard month of 30 days of 12 hours possible sunshine; 'e' was a function of the mean monthly temperature in degrees centigrade, 't',—

$$\frac{e}{e_1}=\left(\frac{t}{t_1}\right)a \qquad \ldots \quad (II)$$

where 'a' is some function of the climate in which the relationship was to be applied and is expressed by the formula—

$$a=675\frac{I^3}{10^9}-77{\cdot}1\frac{I^2}{10^6}+17{\cdot}92\frac{I}{10^3}+0{\cdot}49239 \qquad \ldots \quad (III)$$

'I' is 'heat index' composed of the sum of the twelve monthly values of—

$$I=\left\{\frac{t}{5}\right\}1{\cdot}514 \qquad \ldots \quad (IV)$$

By substituting for 'I' in equation (III) the final relationship was expressed as—

$$e=1{\cdot}6\left\{\frac{10t}{I}\right\}a \qquad \ldots \quad (V)$$

All these correlations involve temperature and are presumed to have been obtained principally because air temperature acts as a crude summation of the meteorological factors really controlling evaporation. There is also good reason for believing that incident radiant energy, under conditions where other meteorological factors are largely controlled, e.g., in a greenhouse, can be correlated with evapotranspiration (9) and indeed, it has been correlated even under the field conditions in Hawaii by Baver (2).

The relationships so far discussed have been entirely empirical and are not based upon scientific principles. Nevertheless, provided they are applied within certain limits of crop type and geographical position, they have enabled weather-based control of irrigation to be almost reduced to a routine (3), (18).

Penman working in Britain approaches the subject differently (13). Commencing with the physical principles involved in evaporation, he has used empirical constants only in so far as ignorance made this necessary. It was assumed that, evaporation being a change of state, is controlled by solar energy surplus after making allowance for radiation losses by reflection from the sky and the earth's surface and a net loss in long warm radiation from the earth's surface to the sky as well as the loss of heat by convective transport from the earth's surface to the atmosphere. On the other hand, the continued uptake of vapour by the air could also be considered in terms of the air vapour pressure gradient and wind turbulence above the evaporating surface. By a combination of these two approaches an equation was developed expressing evaporation from a free water surface (E_o) in the following terms :—

$$E_o=\frac{0{\cdot}27E_a+\triangle H}{0{\cdot}27+\triangle} \qquad \ldots \quad (VI)$$

where $$E_a=0{\cdot}35(e_a-e_d)\left(1+\frac{u}{100}\right) \qquad \ldots \quad \text{(VII)}$$

and $$H=R_a(1-r)\left(0{\cdot}18+0{\cdot}55\,\frac{n}{N}\right)^{*}-\sigma-T^4(0{\cdot}56-0{\cdot}092\sqrt{e_d})\left(0{\cdot}1+0\,9\,\frac{n}{N}\right) \qquad \ldots \quad \text{(VIII)}$$

R =Short wave incoming radiation in the absence of an atmosphere
r=Radiation reflection coefficient
σ =Stefan's constant
σ T=Temperature of air
$e_a e_d$=Saturation vapour pressures at air and dewpoint temperatures
n/N=Ratio actual/possible hours sunshine
u=Horizontal wind speed at two metres height
$\Delta=\frac{de_a}{dT_a}$

Penman was able to show that the estimates obtained by the above equations agreed well with observed measurements in temperate latitudes (13).

In irrigation control, it is evapotranspiration with which we are ultimately concerned and therefore with the utilization of energy falling on leaf canopies, i.e., on their projected area on a horizontal plane, and the evaporation of water, principally from stomata. Consequently, the value for the radiation reflection coefficient "r" in equation (VIII) is different, being now that appropriate to the leaf canopy. Furthermore, whereas evaporation from a free water surface takes place from a continuous saturated surface, evaporation from a leaf is from stomata or small orifices. To the sum of the resistances encountered by each stream of vapour moving through and out from the orifices before the vapour streams emerge, must therefore be added the resistance encountered by the merged vapour streams moving away from the leaf as a whole. And, since the resistance to diffusion is through orifices, the size and spacing of stomata canbe shown to be very small (under conditions of normal ventilation) compared with the resistance to diffusion away from the leaf as a whole, a freely transpiring leaf should act in a manner similar to a saturated surface when the stomata are open, and transpiration should depend primarily on the prevailing meteorological conditions and should be very little influenced by the differences between leaves of various plants. Under these conditions there should therefore be a relationship between transpiration from a leaf canopy and evaporation from a free water surface—and hence the concept of a "transpiration/evaporation" ratio f where $E_t/E_o=f$.

The ratio will clearly be affected by season since stomata normally close at night, cutting off transpiration, whilst evaporation from free water surfaces continues at a reduced rate. In Britain, "f" varies between 0.8 in summer and 0.6 in winter, the spring and autumn values being 0.7 (13)(14). In low latitudes "f" might be expected to be more nearly constant.

*The equation which has been used in the work which follows has (0. 18+0.55 n/N) (the relationship between Rc/Ra found by Penman to apply in temperate latitudes) replaced by (0.25 +0.54 n/N) which is the relationship found by Prescott (17) to apply in Australia.

By the application of physical reasoning, Penman and Schofield (16) were able to express the basic equation governing evapotranspiration from a leaf canopy in the form—

$$E_t = \frac{\triangle\ H_t + 0{\cdot}27E_a}{0{\cdot}27/SD + \triangle} \qquad \ldots \quad (IX)$$

S is an expression dependent upon stomatal geometry and wind speed, and D is an expression which accounts for the diurnal opening and closing of the stomata. If certain simplifying assumptions are made as to the geometry of the stomata and by assuming that the stomata are closed at night and open during the day, while the vapour pressure in the leaf varies sinusoidally, S and D can be calculated. For temperate latitudes, the values of E_t and E_t/E_o for a number of crops have been shown to be in close agreement with measured values (5).

It should be stressed that the theory outlined takes into account not the transpiration from a crop, but the total evaporation from the cropped area including transpiration, evaporation from the soil, and evaporation of intercepted water. It is also believed to account for condensation of water on the leaf surfaces or on the ground. An interesting corollary is that water precipitated on the leaves, and evaporated from them directly during the time when the plant would otherwise have been transpiring, is as useful in reducing the water requirements of the crop as is water applied to the soil and subsequently transpired.

When the vegetative canopy is not complete, the problem of estimating water losses is more complicated. Transpiration from the canopy and evaporation from the soil will proceed to some extent independently and under such conditions a simple estimation of the total water loss will probably have to be derived from empirical relations. The problem is of interest in sugarcane irrigation during that interval in which the canopy expands to shade the soil completely—an aspect which is discussed later in this paper.

The nature of the investigations undertaken: The results which follow deal with the application of meteorological data to the evaluation of evaporation from a free water surface and the transpiration from a continuous canopy of sugarcane in the tropics. The principal published relationships between meteorological data and evaporation from a free water surface have been the subject of critical evaluation. Lysimeter studies have been carried out to evaluate accurately the transpiration from a continuous sugarcane canopy and the relationship between such transpiration and the evaporation from a free water surface, as well as to cast light on the rate at which soil water is lost during the period when the canopy is expanding. Independent estimates of the ratio of transpiration/evaporation (f) from a free water surface have been obtained from an analysis of elongation rates of sugarcane with respect to rainfall, irrigation, and evaporation obtained in an overhead irrigation experiment in which water was applied after two different intervals of evaporation. In so far as the authors are aware, this is the first occasion on which evapotranspiration has been evaluated by this means. Penman's theoretically derived formula for evapotranspiration has been examined and shown to conform to the evapotranspiration from sugarcane provided a special value for S is used.

PART II

THE RELATIONSHIP BETWEEN METEOROLOGY AND EVAPORATION FROM A FREE WATER SURFACE

The Meteorological Station and instruments used :

In March 1954 a meteorological station was set up at an elevation of 43 feet in an open grassed field on The West Indies Sugar Company's Monymusk Estate. The climate and the flat topography of the area are typical of most Jamaican irrigated estates. The station comprised the following instruments :—

(*i*) *Temperature.* Recordings were obtained from a bimetallic thermograph in a standard Stevenson screen. Average daily temperatures were found by integration of the traces with a planimeter. The instrument was checked against readings of maximum and minimum thermometers and the daily 8 a.m. reading of an ordinary thermometer.

(*ii*) *Humidity.* A hair hygrograph was used and the recordings treated similarly to those of temperature. The instrument was adjusted when necessary with reference te the readings of an Assman Psychrometer. The 8 a.m. readings of standard wet and dry bulb thermometers gave false estimates of humidity owing to lack of ventilation.

(*iii*) *Sunshine and Radiation.* The daily durations of sunshine were found using a Campbell-Stokes recorder. Recordings of total radiation were obtained with a modified Robitzch radiation recorder loaned by the British Air Ministry Meteorological Office, and calibrated by them. The instrument records the difference in movement of two bimetallic strips one of which is blackened and exposed to the sky. Daily radiation totals were obtained by integration of the traces.

Both instruments were mounted on 8 ft. plinths and had practically unobstructed horizons.

(*iv*) *Wind.* A three cup totalising anemometer was employed at a height of two metres, and the scale read daily.

(*v*) *Rainfall.* A 5″ diameter standard gauge was used and continuous recordings obtained with a Dines tilting syphon gauge.

(*vi*) *Evaporation.* Readings of the water level in a Standard Meteorological Office pattern tank were made at 8 a.m. daily with a hook gauge. The tank is 6ft. × 6ft. × 2 ft. deep with a rim 1-1/2″ above the ground level. Readings of level were also taken in three 2 ft. diameter cylindrical tanks, two of which are 18″ deep and one 12″ deep. The grass in the enclosure was cut short and frequently watered, the tanks thus being surrounded by a freely transpiring surface.

TABLE I

Months	Mean Temperature (°F)	Mean Humidity (%)	Wind Speed (Miles/Day)	Sunshine (Hrs./Day)	Possible Sunshine (Hrs./Day)	Daily Radiation in the absence of an atmosphere (Units of heat required to evaporate one mm. of water)	Measured Open Water evaporation (Inches)	Penman's Estimated Open Water Evaporation (Inches)	Measured Open Water Evaporation (Inches Day)	Equation (VI) Penman's Estimated Open Water Evaporation (Inches/Day)	Equation (V) Thornthwaite's Potential Evapotranspiration (Inches)	Equation (1) Blaney & Criddle's Monthly Consumptive Use Factor (F)	Baver's $\frac{T^2}{1000}$	0·786 R
Jan.	72.9	74.4	85	8.22	11.18	11.3	5.51	5.25	0.18	0.17	4.06	5.70	5.31	5.78
Feb.	73.6	78.5	109	8.61	11.56	12.7	5.77	5.54	0.21	0.20	4.05	5.37	5.42	6.52
Mar.	72.3	79.7	108	7.88	12.02	14.3	6.93	6.52	0.21	0.21	4.32	6.13	5.30	6.81
Apr.	78.1	78.9	132	7.61	12.55	15.3	7.50	7.36	0.25	0.25	7.00	6.64	6.10	6.97
May	79.5	79.9	122	8.34	12.97	15.8	8.19	8.03	0.26	0.26	8.94	7.22	6.32	7.34
June	80.4	80.2	72	7.73	13.19	15.8	7.28	7.30	0.24	0.24	8.88	7.17	6.46	7.08
July	80.7	78.2	135	8.27	13.10	15.8	8.24	8.27	0.27	0.27	9.37	7.38	6.51	7.34
Aug.	79.4	80.1	108	7.91	12.73	15.4	7.52	7.58	0.24	0.24	8.12	7.07	6.30	7.07
Sept.	78.9	85.0	94	6.17	12.24	14.7	6.04	6.22	0.20	0.20	7.31	6.53	6.23	6.05
Oct.	78.6	86.4	78	6.69	11.74	13.4	5.99	6.07	0.19	0.20	7.06	6.45	6.18	5.87
Nov.	75.6	82.3	69	8.15	11.30	11.8	5.08	5.34	0.17	0.18	5.09	5.79	5.71	5.09
Dec.	75.6	78.2	83	8.66	11.07	10.9	5.28	5.37	0.17	0.17	5.14	5.85	5.71	5.78
					Total Annual		79.33	78.87	—	—	79.34	77.29	71.55	79.50

RESULTS

In Table I are given the monthly values of the meteorological factors influencing evaporation from April 1954 to March 1955, together with the measured values of the evaporation from a standard tank. The values for evaporation derived by using the relationships of Baver (1), Blaney and Criddle (Equation 1), Thornthwaite (Equation V) and Penman (Equation VI) are also included, as are those derived from an empirical regression between total short wave radiation (Rc) received at ground level from the sun and evaporation from a free water surface. The correlations between derived estimates of evaporation and measured evaporation are given in Table II and are presented diagramatically in Fig. 1.

TABLE II

CORRELATIONS BETWEEN EVAPORATION AND ESTIMATES OF EVAPORATION

	r	r^2x100*
Penman	0.985	97
0.786 Rc	0.943	89
Blaney and Criddle	0.859	74
Thornthwaite	0.788	62
Baver	0.648	42

*r^2x 100 is the % extent to which derived estimates of monthly evaporation agree with the measured figures.

It is clear that estimates based upon temperature data alone are far from precise under Jamaican conditions, which may well apply to many tropical or maritime climates where the annual range of temperature is small. Blaney and Criddle's estimate is a great improvement on Thornthwaite's and Baver's, but even so, it only agrees to the extent of 74% with measured evaporation. The Blaney and Criddle equation, by taking into account the length of possible daylight as well as temperature, becomes itself a loose function of radiation, particularly under conditions where the variation in amount of cloud is small, such as is the case at Monymusk and in the tropics where the seasonal variation in possible radiation intensity is also relatively small. It therefore correlates more closely with measured evaporation. The tables show that total short wave incident radiation at ground level Rc* correlates very closely (to the extent of 89%) with measured evaporation and therefore, that all the other factors combined are only one eighth as important as radiation. The importance of radiation was also demonstrated by Baver (2) in Hawaii.

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*Incident short wave radiation at ground level was calculated from Prescott's equation (17) found to apply in Australia— $\frac{Rc}{Ra}=0.25+0.54\frac{n}{N}$ ... ...(X)

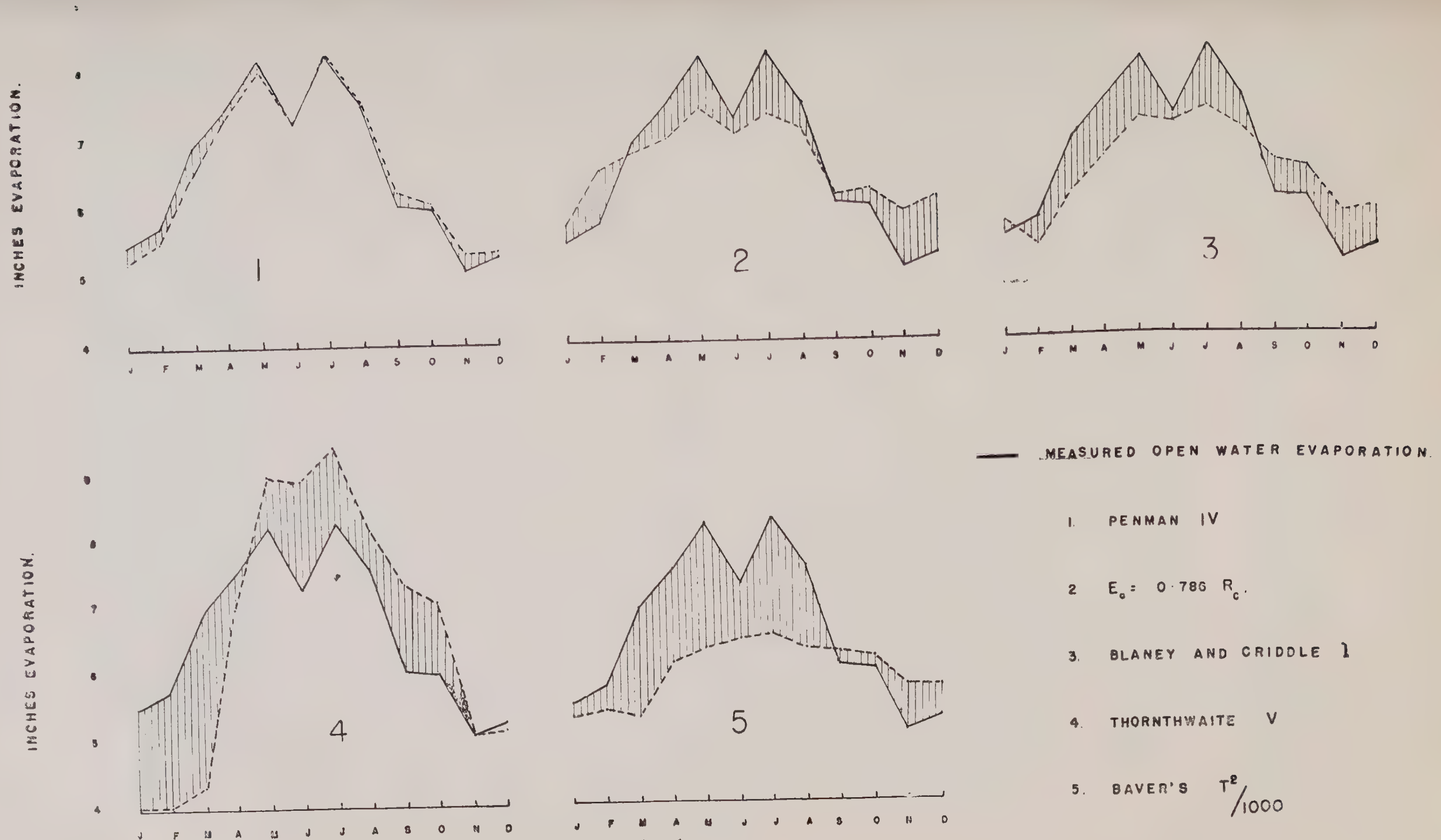
INCHES EVAPORATION.
8
7
6
5
4
J F M A M J J A S O N D
1
2
3
INCHES EVAPORATION.
9
8
7
6
5
4
4
5
MEASURED OPEN WATER EVAPORATION.
1. PENMAN IV
2 $E_o = 0 \cdot 786\ R_c$.
3. BLANEY AND CRIDDLE 1
4. THORNTHWAITE V
5. BAVER'S $T^2/1000$

Fig. 1.

The most accurate correlation of all, which agrees with monthly measured evaporation to the extent of 97%, is that arrived at from an application of Penman's equation (VI).

PART III

THE RELATION BETWEEN EVAPORATION FROM A CONTINUOUS SUGARCANE CANOPY AND EVAPORATION FROM AN OPEN WATER SURFACE

(a) *By theoretical estimation*: Theoretical estimations of the factor $f = E_t/E_o$ can be made if information is available concerning the resistance to diffusive flow across a leaf of the plant considered and crude estimates can be made by idealising the geometry of the leaf stomata (16). The factor S in equation (IX) involves a quantity L_s termed by Penman and Schofield the "effective length" of the leaf surface, which is the extra resistance per unit area encountered by the water vapour in moving out of and away from the stomata above that encountered by the vapour in moving away from the leaf as a whole.

Table III contains estimates of E_t/E_o assuming three different values of L_s, and using the meteorological data found in Table I.

(b) *By lysimeter (Schofield-Cowan type) studies*: The evapotranspiration of plants grown in a lysimeter can be equated to the difference between rainfall plus irrigation, and drainage, provided the changes in stored soil moisture are negligible over the period considered. In order that the results should be applicable to field crops, the lysimeters should be arranged so that the exposure of the experimental plants is typical of the plants in a field, and a sufficient number of plants is used to take into account the natural variability of plant size.

A new type of lysimeter which lent itself to the above requirements was developed. This was constructed from an open oil drum (44 Imperial gallons), into the bottom of which was welded a small sump (see Fig. 2). A wire grid three inches above the base of the drum supported the soil which filled the drum to within two inches of the rim. The soil was graded in decreasing coarseness from small pebbles in the lowest horizon to well structured clay loam in the top. A 1/4″ galvanised iron pipe placed in the sump facilitated the removal by suction of drainage water in the bottom of the tank, a second pipe providing an air inlet. Twenty-four such drums were sunk flush with the ground level inside a cane field on Monymusk Estate. They were arranged in four rows of six, the rows being 4′6″ apart and 12′ in length, and each drum was planted with one sett of cane. The spacing of the plants was then similar to that in the rest of the field. To ensure that any rain falling on an area 12′ × 18′ should be guided into one or other of the tanks, the surface between the tanks was covered with a layer of concrete ridged and moulded in such a way that each tank occupied a catchment 2′ × 4′6″. Thus the installation was equivalent to one large tank containing 24 cane stools, but with the advantage that the behaviour of each plant could be

TABLE III

THEORETICALLY DERIVED VALUES OF E_t AND f

Months	D	S	L_s=0.16 cms.		L_s=0.0.32 cms.			L_s=0.64 cms.		
			E_t Inches/ Month	$f=E_t/E_o$	S	E_t Inches/ Month	$f=E_t/E_o$	S	E_t Inches/ Month	$f=E_t/E_o$
January	0.91	0.69	3.38	0.61	0.53	3.02	0.55	0.35	2.48	0.45
February	0.97	0.66	3.94	0.68	0.49	3.50	0.61	0.32	2.71	0.47
March	1.06	0.66	4.80	0.69	0.49	4.27	0.62	0.32	3.48	0.50
April	0.98	0.64	5.40	0.72	0.47	4.69	0.63	0.31	3.90	0.52
May	0.93	0.65	5.52	0.67	0.48	4.97	0.61	0.32	4.10	0.50
June	0.91	0.70	5.28	0.73	0.54	4.52	0.62	0.37	4.11	0.56
July	0.97	0.63	6.04	0.73	0.46	5.38	0.65	0.30	4.26	0.52
August	0.96	0.66	5.31	0.71	0.49	4.96	0.66	0.32	4.10	0.54
September	1.03	0.67	4.68	0.76	0.51	4.23	0.70	0.34	3.57	0.59
October	1.11	0.70	4.59	0.77	0.53	4.22	0.70	0.36	3.24	0.54
November	1.01	0.70	3.92	0.77	0.54	3.54	0.70	0.37	2.99	0.59
December	0.95	0.69	3.75	0.71	0.53	3.31	0.63	0.36	2.76	0.52
Mean		—	—	0.71	—	—	0.64	—	—	0.53

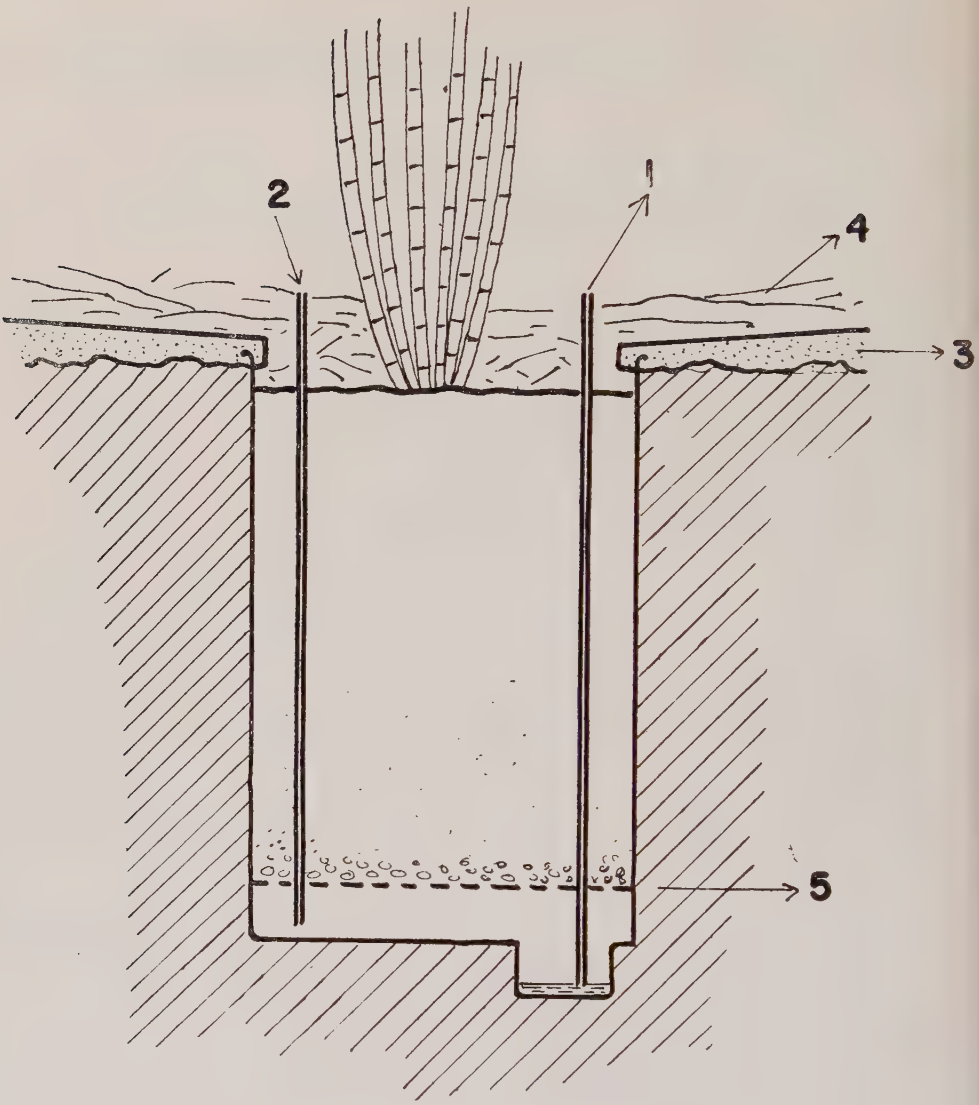

FIG. 2

1. SUCTION THROUGH CALIBRATED ASPIRATOR
2. AIR VENT 3. CONCRETE CATCHMENT
4. SURFACE TRASH 5. GRID

studied separately. The whole was surrounded on all sides with sugarcane watered by surface irrigation such that the growth of the canopies inside and outside the installation was uniform.

During the first four months, growth of the setts, i.e., prior to November, this development with respect to the surrounding cane was judged to be not even enough. The cane in the lysimeters and the surrounding cane in the field were therefore cut back and second growth allowed. This proved very uniform. The trash from the first cutting was laid evenly between the cane rows on the surface of the soil and concrete.

Every two to four days in the absence of rain, throughout the duration of the experiment, measured quantities of water, estimated to be rather more than sufficient for the plants' needs, were poured uniformly over the soil surface of each tank. At intervals of about one week while the cane was young and later at two weeks, the excess water which had drained through the soil in the tanks was pumped out and measured.

RESULTS

The recording was commenced on the 10th November 1954 when the cane was three weeks old. The tanks were pumped out twice—on the 10th and 17th—before any water was applied as they had been flooded by fall rains. Measurements were continued until the 1st June 1955, after which rains again flood the tanks.

The cane was reaped at the end of August 1955 and the weight of each stool determined. During the course of the experiment, the mean quantity of water consumed per lysimeter was $21.8'' \pm 1.6$ and the average weight of cane reaped per lysimeter was 18.6 ± 3.6 lbs.

The increasing quantities of water, with respect to time, used by the station as a whole, are presented as inches of water (over the total area of the station) in Fig. 3. During November, December and early January the rate of consumption increased from a negligible initial value as the canopy closed in. This stage is indicated by the AB in the Figure. The mean value of 'f' obtained from mid January, when the canopy was approximately continuous, to June, was 0.57. The values for the $\Sigma 0.57E_o$ from mid January onwards have also been plotted on the same figure and show that the agreement between measured evapotranspiration and $\Sigma 0.57\,E_o$ has been very close indeed—so close that $\Sigma 0.56E_o$ accounts for over 99% of the variation in the Σ evapotranspiration of the station ($100\,r^2 = 99.3$). It is therefore reasonable to assume that any seasonal variation in the value of 'f' must have been small.

Approximately two thirds of the floor area occupied by the station was sealed with a series of concrete catchments and therefore, soil moisture losses through the ground surface of the station were reduced to the order of two-thirds of those under normal field conditions. Consequently, it is important to have a clear picture of the order of magnitude of the error so introduced into measured value of 'f'.

Measurements showed that the evaporation from an open water surface was ten times that from a similar surface placed under a continuous cane canopy. Therefore, the maximum correction to the value of ‘f’ as measured, even where the area under the cane canopy was all a water surface, would have been only +0.06. But the correction with which we are dealing refers to a soil surface and one which would have had a dry surface layer of trash and soil for most of the period, through which surface the loss of water would have been negligible (11) (13). It seems reasonable therefore to assume that the error in the measured value of ‘f’ is very small.

The water loss in the period during which the canopy was developing, i.e., AB in Fig. 3 can be taken as approximately that shown in the graph since the error in ‘f’ at B has been shown to be very small, and the rate of loss at A, even if three times the recorded rate of loss, was still negligible.

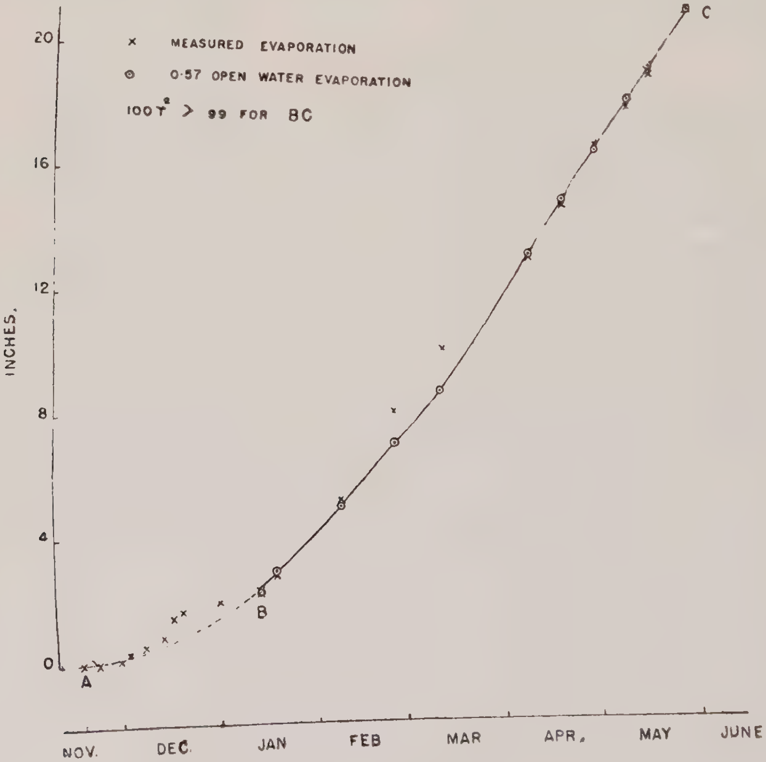

Fig. 3.

The relatively high consumption of water in the latter part of December was probably due to the retention, after the heavy rains on the 14th and 19th, of excessive soil moisture in the tanks.

The variations both in stool weight and the water used per lysimeter were so small as to render no correlation possible between the two sets of data.

(c) *By sugarcane elongation studies*: Penman's theory indicates that the rate of evaporation from a cane field in which the canopy is established is related to that from an open water surface by the relation—$Et=fE_0$, and defines soil moisture Deficit as the accumulated difference between evapotranspiration and precipitation P; the summation extending from the time the soil was last at field capacity, i.e.,

$$\text{Deficit}=f\ \Sigma\ E_o—\Sigma\ P$$

Previous investigators have shown that under conditions where irrigation is necessary, the biggest single factor influencing the growth of cane, is the level of soil moisture. There should therefore be a close relationship between growth (G) and soil moisture Deficit, i.e.,

$$G=\text{function(Deficit)}=\text{function}\ (f\ \Sigma E_o—\Sigma P) \qquad \text{(XI)}$$

A linear regression of growth on accumulated open water evaporation and accumulated precipitation will have the form—

$$G=a\Sigma E_o+b\Sigma P+c$$
$$=b\left(\frac{a}{b}\Sigma E_o+\Sigma P\right)+c$$

Provided neither E_o nor P influence growth except in so far as they influence soil moisture Deficit, comparison of equations (XI) and (XII) yield the indentity—

$$f=\frac{-a}{b}$$

The Experiment: A small overhead irrigation unit employing four No. 40 Rainbird rainers was used to irrigate four plots each 36′ square on a heavy clay soil on Monymusk Estate. The four rainers working at the corners of a plot gave an extremely even application of 1/2″ per hour under still conditions, the quantity and distribution at each irrigation being checked by the collection of precipitation in a quart can supported just above the cane canopy.

The lengths* of twenty selected canes in the centre of each plot were measured at intervals of two to three days and irrigation applied when a significant drop was registered in growth rate. The quantity of water used per irrigation varied between 1/2″ and 2″ as conditions permitted. Such applications were estimated to be insufficient to cause drainage out of the root zone which was shallow (0-18″) and overlaid a stiff structureless clay subsoil. All irrigations were carried out at night under still conditions.

The experiment was commenced on the 9th May when the canopy became continuous and when the cane was three months old and terminated on the 2nd September because of excessive rain. The cane was cut in mid October.

RESULTS

The multiple regression of growth rate upon accumulated open water evaporation (obtained from a nearby meteorological station) and upon accumulated precipitation was found to be highly significant for all four plots. The equations and their significance are given in Table IV.

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*The height between a soil datum peg and the last visible ligule was recorded for each cane.

TABLE IV

THE RELATIONSHIP BETWEEN G (GROWTH RATE), E_0 (EVAPORATION) AND P (PRECIPITATION)
(PERIOD MAY—SEPTEMBER, 1954)

Plot A	$G - 1.81 = 0.43 (P - 0.61 E_0)$	Significant 0.01
plot B	$G - 2.15 = 0.61 (P - 0.58 E_0)$	,, ,,
Plot C	$G - 2.07 = 0.60 (P - 0.57 E_0)$	,, ,,
Plot D	$G - 1.74 = 0.55 (P - 0.55 E_0)$	,, ,,

The agreement between the four estimates of 'f' has been close, giving a mean value of 0.58, which is in excellent agreement with $f = 0.57$ obtained from lysimeter studies. The fact that this relationship was obtained from a study of cane under conditions of limiting soil moisture as well as from the lysimeter measurements where the cane was plentifully supplied with water, suggests that soil moisture deficits over the range encountered do not influence evapotranspiration greatly.

GENERAL DISCUSSION

Our observations show that Penman's equation (VI) gave a very close estimate of evaporation from a free water surface under Monymusk conditions and accounted for 97% of the monthly variation in evaporation. The greatest single meteorological factor controlling evaporation was incident radiation which accounted for about 90% of the variation in monthly evaporation and was probably the reason why Blaney and Criddle's equation (I) gave a better estimate of evaporation from a free water surface than did the other empirical equations.

The relationship 'f' between the water lost to the atmosphere from a given area of vegetation (or crop) and the water evaporated from an equal free water surface has been examined by other investigators under non-tropical conditions. It is improbable that Blaney and Criddle's (3) "consumptive use factor f" gives an accurate measure of evaporation from a free water surface and therefore it is doubtful to what degree their "consumptive use coefficient K" approximates to f ($= E_t/E_o$). Musgrave (10) has indicated that, on the average, crop plants give values of 'f' of about 0.60* whilst Penman (14) obtained a mean annual value in the United Kingdom of 0.70, whilst for lucerne in Australia he obtained 0.61 (15). The only detailed work on the "consumptive use" of sugarcane known to the authors is that of Fuhriman and Smith (8) which was carried out in Puerto Rico under conditions very similar climatically to Monymusk. The data suggest that the "consumptive use coefficient K" varied greatly from month to month even after the cane canopy was fully formed and that it was about "0.86 for the fall season peak water use". It seems probable that the "consumptive use" figures used were all too high by an unknown, but nevertheless appreciable margin, for the reason that they were computed from the difference in the moisture content of the soil before and after irrigation, i.e., some of the water debited to consumptive use would have been lost by drainage. This error was probably least in the fields irrigated by overhead irrigation. In these fields we estimate 'f' as being of the order of 0.73 for the period between when the cane was five months old and when water was withheld prior to ripening. The evaluation of "consumptive use" by the field methods used by Fuhriman and Smith entailed an enormous effort but unfortunately, as an analysis of their data shows, their values of K must have been subject to considerable errors inherent in the methods themselves—such as soil heterogeneity, sampling errors, assumptions about rainfall utilization, etc. We are inclined therefore to accept their mean values of K as very broad estimates.

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*Using standard open pans of the U.S. Weather Bureau.

Our lysimeter data obtained at Monymusk have shown that the monthly evapotranspiration or moisture lost (E_t) from a given area of cane canopy plus that lost through the lysimeter station surface between January and June was adequately accounted for by the relationship $E_t=0.57E_o$. In future, the lysimeters require modifying in order that the measurements may be checked during the season of heavy rains in the autumn, although, as far as irrigation control is concerned, this period is relatively unimportant. The only other data reported on the "consumptive use" of sugarcane based upon lysimeter studies, are figures given by Fuhriman and Smith (8). Their figures are extremely high indeed—higher than the values derived from their field experiments, and could be explained on the basis of the projected horizontal area occupied by the cane being appreciably greater than that of the lysimeter. It is important in studies such as these that the spread of the canopy should conform to the horizontal area of the lysimeter station.

An independent estimate of the constant 'f' equal to 0.58, was obtained from cane elongation studies on four plots of an overhead irrigated experiment also at Monymusk, between May and September. The extremely close agreement obtained is probably partly fortuitous. The values agree well with those reported by Musgrave (10) for other crops and for Penman's (15) value for lucerne in Australia.

The theoretical values of 'f' derived from meteorological data and leaf characteristics using Penman's formula (IX) suggest that the value of 'f' varies with season to a degree greater than was indicated in our experimental data and that a mean value of $f=0.58$ would mean that the "effective length" in the formula should be of the order of 0.42 cms.—a figure which appears a little on the high side.

The fact that leaf elongation was found to vary linearly with accumulated soil moisture deficit would tend to confirm the findings of Waterhouse and Clements (21) that the reaction of the cane plant is sensitive to changes in soil moisture, even at low tensions.

SUMMARY

The principal relationships between meteorological factors, evaporation and transpiration have been reviewed and compared with actual monthly evaporation from a free water surface. The closest agreement was given by the Penman-Schofield relationship.

The value for the ratio between evapotranspiration from sugarcane, once the canopy was complete and evaporation from a free water surface was determined by two independent methods and found to be of the order of 0.58.

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CULTURAL

Mr. Mohan Rao then presented the following paper.

Paper

STUDIES ON SUGARCANE RATOONS

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INTRODUCTION

Ratooning of cane has come to stay as one of the important agricultural aspects in Andhra State. Cane cultivators take to ratooning because of the lower cost of cultivation involved. From the factory view point, wherever a well planned, varietal schedule is absent, ratoons play the part of early varieties since they come to maturity earlier in the season and give higher recovery. Unfortunately, in many areas of the State, ratoons are taken as "free" crops and indiscriminate number of ratoons are taken; because of the latter practice there is more incidence of disease and the yields have become sometimes uneconomic.

Ratooning is a justifiable practice provided sufficient care is taken, in the cultural and manurial aspects, and experiments have shown that ratoons can be made to yield as much as plant crops.

Information is lacking as to why exactly ratoons yield lesser than the plant crops, whether it is due to an exhaustion of plant nutrients by the preceding crop or whether it is due to inherent physiological incapacity of the ratoons to take up nutrients or whether it is due to defective cultural and manurial techniques is not known. Definite information is wanting on the economic number of ratoons to be taken both in respect of yield of cane or sugar.

Ratoons play a very important role in the agricultural economy of the cane cultivator and in the manufacture of sugar. The need has been felt or comprehensive information for successful growing of ratoons for stabilizing the sugar industry in the State.

In the following pages data are presented to indicate the optimum number of ratoons to be taken, the optimum time, dose and form of manure to be applied and an attempt has been made to indicate the probable causes for the lower yields of ratoons.

REVIEW OF LITERATURE

Varieties differ considerably in the manner in which they respond to ratooning (2, 8, 29). Certain of the Coimbatore seedling canes have been known to give higher yields as ratoons than as plant crops (29). Varieties like Co.421 are more profitable as ratoons than as plant crops. Co.419 recorded high yields even as a ratoon (19). The low yields of ratoons with similar dose of manure as for plant crop and the higher yields of the first two ratoons with increased doses of manure show that ratoons need heavier manuring (8). Yield of ratoons are less than plant crops under the same cultural and manurial treatments. The optimum dose of nitrogenous manure is higher for ratoon than for plant crop and under Anakapalle conditions it is 50 pounds more per acre over the optimum dose for plant crop (24). It has been reported from Uttar Pradesh (3) that harvesting of plant cane from mid February to mid April appeared to be the best for ratooning in general and higher yields of ratoons were obtained with trench planted cane harvested at ground level and manured with 120 lbs. nitrogen per acre, half applied at harvest of plant crop and half at the break of rains.

Ross (22) observed that moderate applications of superphosphate to ratoon cane appeared to increase the action of sulphate of ammonia but heavy applications reduced it. Sherrard (25) reported that top dressings of 300-400 pounds per acre of ammonium sulphate and sodium nitrate applied to plant canes 3-6 weeks after planting and to ratoons approximately the same time after cutting gave economic responses in seasons of reasonable rainfall. A top dressing of phosphorus to ratoons which had received basal dressing of phosphorus in the plant cane stage gave no response and the application of phosphorus other than in the furrow at planting was of no value. Organic manures increased yield and ratooning power particularly on soils with a shallow surface soil and a sub-soil not easily penetrated by roots (14). Experiments on sandy soils at Mtunzini recorded significant yields when potash at the rate of 200 pounds per acre was supplied in various combinations with nitrogen and phosphorus to first ratoon crop but such response was rare in Natal Sugar Belt (12 & 7). Knowels *et al* (16) reported that super phosphate applied with ammonium sulphate had no effect on the first ratoon yields on the two soils of British Guiana investigated; ammonium sulphate applied in excess of the recommended standard dressing of 4 cwts. per acre might increase first ratoon yields and neither phosphatic fertilizer nor the proprietary compound "limex" had any beneficial residual effects on subsequent ratoons.

Samuels *et al* (23) summarising the results of experiments with the first cycle of a plant cane and four ratoons, stated that application of nitrogen gave the highest increase of 96° available sugar yields; potash fertilizers did and phosphatic fertilizers did not increase the yields of sugar; nitrogen and phosphorus did not influence sucrose concentration, which however decreased in absence of potash. Plant and ratoon crops varied in their requirements of nitrogen although the amounts of phosphorus and potash remained relatively the same and normal application of fertilizers is to be made as soon as the plant cane is cut. Placement of fertilizer close to the stools at a depth of 3″ or 4″ is desirable (15). A ratoon crop of Co.453 yielded about 75 tons (2036 maunds) per acre with 200 lbs. nitrogen in Uttar Pradesh (11). Nagar (18) reported gradual increase in the yields of the first, second and third ratoons at Shahjahanpur, when the nitrogen was applied at 100 pounds per acre. It was concluded after considerable experimentation at

Kalai in Uttar Pradesh (17) that the extra cost involved in higher manuring to ratoons was amply compensated by increased yields and better juice extraction. Plant crops are more efficient users of applied nitrogen than ratoon cane and the plant crops needed for their optimum yields less than 2 pounds of nitrogen per ton of cane harvested where as the ratoons required 2½ pounds (5). Evans (10) studied the effect of late application of N on a first ratoon crop in Mauritius. The increase in millable stalks over the control was attributed partly to increased production of new stalks after extra application of nitrogen and partly to a greater rate of survival among the shoots thus formed.

Hardy (13) reported that the shoots of ratoon plant originate at a higher level than those of first year plant. Evans (9) found that the root system of a ratoon crop is more shallow than that of a plant crop at least as far as the absorbing system is concerned. He further stated that it is a process of gradual replacement of the older roots inherited from the previous crop functioning side by side with the new system formed from the ratoon shoots for a time. Shoot roots like sett roots die after a time, their place being taken by new roots and the almost, continuous production of fresh roots enables the cane plant to quickly adjust itself to changing environmental conditions (30). Studies at Anakapalle revealed that shoot root formation is somewhat delayed when sett roots are present. It is therefore surmised that shoot root formation in ratoons is later than in plant crop. Further it was noticed that the region of the shoot below the ground level is shorter in the ratoon than in the plant crop. The average number of root forming internodes in the plant and ratoon crops was found to be 8.2 and 5.3 respectively (2). Ratoons are less resistant to drought than plant crop due to shallow root system (28).

Ratoons mature earlier than plant crops (8, 19 and 24). Moisture content in plant parts falls progressively as the cane matures. A close relationship is observed between earliness of cane and the moisture content of the tissues (20). Arrowing is more in ratoons than in plant crops and it is less with increase in dose of nitrogenous manure (19 and 24). Ratoons are found to be more susceptible to insect pests and also to smut (1,2,8,19 and 24). Fertilized ratoons are much less subjected to attack by top borers and the whitefly (18).

MATERIALS AND METHODS

(a) Studies were carried out at Anakapalle with Co.419 to determine the nature of nutrition, growth and development, effects on the soil composition, and yield and juice quality of the plant crop, first and second ratoons during the years 1947-48 to 1949-50. The lay-out of the experiment was in split plot design with plant crop, first ratoon and second ratoon as major treatments and nine manurial doses as minor treatments. The doses of manures consisted of 100 lbs. 150 lbs., and 200 lbs., of nitrogen in combination with 0 lb., 50 lbs., and 100 lbs., of phosphate per acre. Nitrogen was supplied in the form of groundnut cake and ammonium sulphate in 2:1 ratio of nitrogen and phosphate was supplied in the form of superphosphate. The manures were applied in two equal doses, half at planting and the remaining half at the time of earthing up in June. All the treatments received a basal dressing of 10 tons of farmyard manure per acre. The soil was a clay loam of medium fertility. The nutrition studies were conducted in the plant crop, first and second ratoons, receiving 100 lbs. nitrogen per acre. Soil samples were drawn from the top one-foot depth at periodical intervals and analysed for important ingredients. Plant samples were also taken simultaneously to study the mineral uptake. Linear growth measurements were recorded in all the treatments. Yields and C.C.S., were determined at harvest. Physiological studies on the hydration of tissues of plant and ratoon crops in relation to their growth and maturity were also carried out.

(b) The water requirement of sugarcane first ratoon (Co.419) in relation to form of manure was studied at this station. The experiment was laid out with two irrigation levels (once in 12 days and once in 24 days) as major treatments and three forms of manures as minor treatments in a split plot design. The manures applied were ammonium sulphate alone, groundnut cake alone and mixture of ammonium sulphate and groundnut cake in 1:2 proportion to supply 100 pounds nitrogen per acre. Fifty pounds nitrogen was applied when the crop was 45 days old and the remaining 50 pounds was given at the time of earthing up in June. No basal dressing with bulky organic manures was given.

(c) The optimum time of application of manure was studied during the year 1954-55 with the first ratoon of Co.419. Manure was applied by placement method to the different treatments at every clump, 3″ to 4″ below ground level. The experiment was a randomised replicated trial with four treatments namely:-

(A1) application of 150 pounds nitrogen per acre in the form of ammonium sulphate, half dose at stubble shaving and the other half 45 days after stubble shaving.

(A2) same as above, half dose 45 days after stubble shaving and the remaining half at 90 days at the time of earthing up in June.

(B1) application of 150 pounds nitrogen per acre in the form of ammonium sulphate and groundnut cake in 2:1 proportion on nitrogen basis, half dose at the time of stubble shaving and the other half 45 days after stubble shaving.

(B2) same as above, half dose 45 days after stubble shaving and the remaining half 90 days after stubble shaving at the time of earthing up.

Data pertaining to the above have been presented in the following pages.

RESULTS AND DISCUSSION

BIO-CHEMICAL STUDIES ON RATOONS

(*i*) *Plant analysis*:—With a view to see whether the plant analysis reflects the causes for the differences between plant and ratoon crops with respect to any nutritive element, the plant, first ratoon and second ratoon were analysed for major plant food elements at different stages of growth, and the results, are presented in Table I.

From the periodical sampling, the uptake per acre of the major plant nutrients was calculated and the same is presented in Table II.

TABLE I

WHOLE PLANT ANALYSIS Co. 419 (PER CENT DRY BASIS)

TREATMENT 100 POUNDS N

Particulars	June			August			November			At harvest (Feb.)		
		1st	2nd		1st	2nd		1st	2nd		1st	2nd
	Plant	Ratoon	Ratoon	Plant	Ratoon	Ratoon	Plant	Ratoon	Ratoon	Plant	Ratoon	Ratoon
Total nitrogen (N%)	2.27	2.05	1.96	1.29	0.94	0.90	0.54	0.67	0.49	0.49	0.51	0.50
Phosphoric acid (P%)	0.65	0.81	0.73	0.79	0.86	0.63	0.63	0.40	0.41	0.61	0.44	0.34
Potash (K%)	0.83	1.02	0.75	1.10	1.54	1.34	1.45	1.03	1.17	1.20	1.39	1.32
Calcium (Ca%)	1.32	1.07	0.95	0.97	0.84	0.70	1.14	1.06	0·87	1.22	1.12	1.01
Intensity of nutrition (N plus P plus K)	3.75	3.88	3.44	3.18	3.34	2.87	2.62	2.10	2.07	2.30	2.34	2.16

The data indicate that the total nitrogen in ratoon crops is lower than that of plant crop throughout the active growth period. In the case of potash, no deficiency can be observed at any stage of growth of the plant. It is found that the calcium status falls and rises with age, the maximum being at the time of harvest in all the three crops. The intensity of nutrition is lowest in the second ratoon crop.

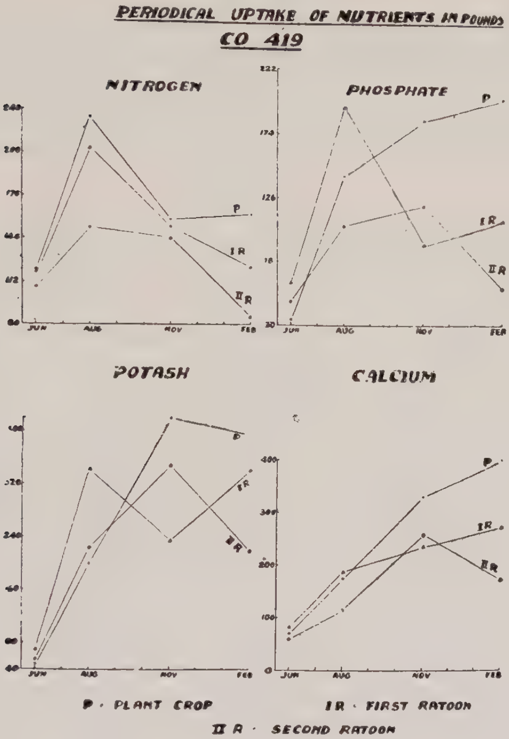
TABLE II

PERIODICAL UPTAKE OF PLANT NUTRIENTS IN POUNDS PER ACRE
Co. 419—TREATMENT 100 POUNDS "N"

Particulars	Plant				1st Ratoon				2nd Ratoon			
	June	August	Nov.	Feb.	June	August	Nov.	Feb.	June	August	Nov.	Feb.
Nitrogen in lbs.	122.69	234.60	157.00	163.10	120.00	211.30	154.50	126.40	108.30	152.54	145.30	86.00
P_2O_5 ,,	34.85	143.70	183.70	201.10	61.98	193.00	91.75	108.20	48.03	105.90	119.60	58.95
K_2O ,,	45.02	199.60	423.10	398.10	69.82	346.50	236.90	342.80	49.43	224.70	348.70	224.10
CaO ,,	71.15	175.70	332.40	404.20	75.58	188.10	243.40	276.70	62.76	116.80	260.10	176.60

The uptake of nitrogen is lower in case of ratoon crops at any stage of growth as compared to plant crop, the gradation being gradual. In the case of other elements the results are not consistent. It appears that the uptake of nitrogen is completed early in the case of plant crop, while the uptake of phosphoric acid and potash continues till late in the grand period. It can be seen that the uptake of nitrogen has been rapid from June and the peak is reached in August. The highest and most rapid uptake is in plant crop, the next being in the first ratoon and the least being in the second ratoon. It can be seen that the uptake of nitrogen has gone down to a very low order in the case of second ratoon (Figure 1).

Fig. 1.



LEAF NITROGEN

Leaf samples from the plant, first ratoon and second ratoon crops were collected at different stages of growth and analysed for nitrogen to see whether leaf composition would indicate the deficiency of the element in ratoon crops compared to the plant crop.

TABLE III

LEAF ANALYSIS OF Co. 419 (% DRY BASIS)
TREATMENT 100 POUNDS N

Particulars	Total nitrogen in leaf 3rd month June	 5th month August	 8th month November
Plant crop	2.53	1.86	1.51
First ratoon	2.19	1.72	1.43
Second ratoon	2.11	1.66	1.16

Leaf nitrogen figures indicated a lower N status in ratoons thereby indicating need for more nitrogen application under the same soil conditions.

SOIL ANALYSIS

In order to examine whether exhaustion of soil by the plant crop is responsible for the lower yields of ratoons, the soils under plant, 1st ratoon and 2nd ratoon crops were analysed for important fertilizer constituents and the results are presented below.

TABLE IV

SOIL ANALYSIS TREATMENT 100 POUNDS N

Month	Crop	'Nitrate' nitrogen M.gms./100 gms. soil	Total nitrogen %	'Available' phosphoric acid %	Available Potash%
March	Plant	0.600	0.084	0.017	0.050
	1st ratoon	0.800	0.069	0.016	0·082
	2nd ratoon	0.800	0.065	0.022	0.043
April	Plant	0.500	0.082	0.030	0.049
	1st ratoon	0.500	0.078	0.036	0.050
	2nd ratoon	0.500	0.069	0.032	0.050
June	Plant	0.600	0.113	0.022	0.055
	1st ratoon	0.600	0.110	0.029	0.067
	2nd ratoon	0.800	0.104	0.028	0.079
August	Plant	0.774	0.071	0.037	0.059
	1st ratoon	0.791	0.069	0.036	0.062
	2nd ratoon	0.697	0.055	0.037	0·072
October	Plant	0.835	0.054	0.025	0.048
	1st ratoon	0.653	0.052	0.026	0.050
	2nd ratoon	0.673	0.051	0.025	0.055
February	Plant	1.690	0.064	0.025	0.106
(At harvest)	1st ratoon	1.542	0.059	0.022	0.034
	2nd ratoon	1.402	0.060	0.028	0.109

Nitrogen status at any stage of growth of the cane plant is of a higher order in the plant crop area as compared to the ratoon area. As the yields in plant and ratoon crops, differ significantly, the figures for nitrogen in ratoon soils can be taken as indicative of deficiency. In the total nitrogen status there is improvement at the harvest time and this may be due to cessation of uptake of plant food elements after attaining maturity. At the grand period stage of the crop, the nitrate nitrogen status is of a lower order in first and second ratoon crops as compared to plant crop. No deficiency is visible in the first and second ratoon soils at any stage of growth in case of available potash and phosphoric acid.

HYDRATION IN PLANT

Treatment with 100 pounds nitrogen without any phosphate application was taken up for studying the ratoons in comparison to plant crop with regard to periodical increase in the dry weight and its relation to the hydration (i.e., amount of water per 100 parts of dry matter). Periodical increase in dry weight of the entire plant is furnished below.

TABLE V

DRY WEIGHT AND HYDRATION IN PLANT AND RATOON CROPS
(Co. 419)

Period	Dry weight			Hydration		
	Plant	1st Ratoon	2nd Ratoon	Plant	1st Ratoon	2nd Ratoon
July	165.6	125.4	111.7	418.7	398.3	—
August	205.4	256.5	153.8	433.3	391.4	404.5
September	305.7	331.6	303.6	414.9	364.3	301.3
November	554.2	481.7	471.6	298.0	281.4	277.6
January	646.7	658.8	532.6	265.4	223.9	271.8
February	758.2	814.4	597.0	258.6	211.6	214.6

The data indicates that the hydration in ratoons is lower than in plant crop and the second ratoon is poorest in accumulation of dry matter. The inverse relationship between hydration and sucrose content, established in certain other plants, may also be applicable in this crop. Thus the lower hydration levels of the ratoons may be the plausible factor for their earlier maturity. Thus conditions leading to higher hydration of ratoons would seem to favour better growth and raise the yield of cane.

YIELD OF CANE

Yield of cane per acre along with weight of individual millable canes under different treatments are furnished below.

TABLE VI

YIELD OF CANE IN TONS PER ACRE AND INDIVIDUAL CANE WEIGHT IN POUNDS Co. 419 (1949-50)

Treatment	Yield of cane in tons			Weight of single cane in lbs.		
	Plant	1st Ratoon	2nd Ratoon	Plant	1st Ratoon	2nd Ratoon
100N Plus 0P	45.80	32.43	24.15	2.87	2.82	2.27
100N Plus 50P	40.73	38.37	29.46	2.82	2.72	2.19
100N Plus 100P	44.61	36.79	27.22	2.97	2.65	2.40
150N Plus 0P	44.51	40.90	36.02	2.87	2.84	2.61

TABLE VI (Contd.)

150N Plus 50P	46.86	38.88	35.25	3.08	3.39	2.58
150N Plus 100P	47.95	38.16	35.63	3.26	2.71	2.52
200N Plus 0P	47.95	36.98	30.57	2.88	2.77	2·58
200 Plus 50P	46.54	39.53	35.28	3.29	2.85	2.54
200 Plus 100P	46.13	40.88	34.71	3.03	2.89	2.57

	S.E.	C.D. when P—0.05
Major treatment—	1.34	4.39
Minor treatments—	1.08	3.04

Results are significant.

FIG 2

CO. 419.

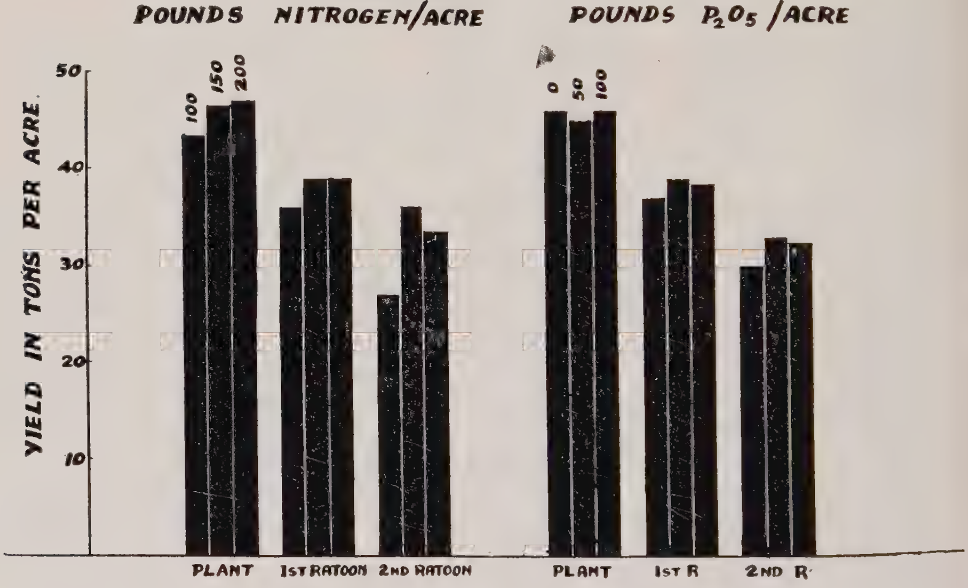


TABLE VII

EFFECT OF NITROGEN AND PHOSPHORIC ACID ON CANE YIELD Co. 419 IN TONS PER ACRE

Particulars	Nitrogen per acre			Phosphoric acid per acre		
	100 lbs.	150 lbs.	200 lbs.	0 lb.	50 lbs.	100 lbs.
Plant crop	43.71	46.44	46.87	46.09	44.71	46.23
1st Ratoon	35.86	39.31	39.13	36.77	38.93	38.61
2nd Ratoon	26.94	35.65	33.52	30.27	33.33	32.52

Soil and plant analysis revealed that in the matter of proper nutrition of ratoons nitrogen appeared to be the chief limiting factor. The data presented in Table VII, showed that increased doses of nitrogen resulted in increased yields of the first and second ratoons. The yield of the first ratoon could be raised considerably but the yield of the second ratoon could not be pulled up to the level of the plant crop or the first ratoon by increased nitrogen doses of even 200 pounds per acre. This is probably due to a set back in the physiological activity of the second ratoon or the need for the other elements in addition to nitrogen. It is interesting to note that in the case of the second ratoon phosphoric acid at 50 pounds per acre tended to raise the cane yields to some extent. It appeared to be necessary that ratoons should be manured early since the ratoons started with an already established root system and showed lower nitrogen in plant from early stages.

CANE MATURITY AND JUICE QUALITY

The results of periodical juice analysis for plant crop, first ratoon and second ratoon are given in Tables VIII and IX.

WATER REQUIREMENTS OF RATOON CROP IN RELATION TO FORM OF MANURE

(*i*) Data on growth measurements at the time of harvest are presented below :—

TABLE X

GROWTH MEASUREMENTS Co. 419 (1953-54)

Particulars	Irrigation once in 12 days			Irrigation once in 24 days		
	Ammonium sulphate	Ground-nut cake	Mixture	Ammonium sulphate	Ground-nut cake	Mixture
Average length of millable cane in inches	105	105	98	86	86	91
Average number of millable canes per plot (2.65 cents)	698	678	740	604	652	597
Average weight of millable cane in pounds	3.25	3.13	2.91	2.78	2.42	2.60
Average length of internodes in inches	4.10	4.07	4.14	3.65	3.50	3.20
Average number of internodes	22	26	24	23	22	22
Average girth of internodes in inches	1.23	1.22	1.17	1.07	1.10	1.11
C.C.S. percentage	7.61	8.28	9.99	7.79	8.66	8.39

TABLE VIII

JUICE QUALITY AND C.C.S. ESTIMATIONS TREATMENT 100 N PLUS ‘O’ POUNDS ‘P’ Co. 419

Particulars	Plant crop				1st Ratoon				2nd Ratoon			
	Nov.	Dec.	Jan.	Feb.	Nov.	Dec.	Jan.	Feb.	Nov.	Dec.	Jan.	Feb.
Brix %	15.69	16.96	19.11	20.14	16.09	17.45	19.91	20.20	17.09	19.15	20.11	20.74
Sucrose %	12.19	14.48	16.65	17.98	12.31	15.36	17.20	18.03	13.75	17.05	18.44	18.80
Glucose %	1.71	1.31	1.25	0.67	1.84	0.97	1.22	0.09	1.99	0.91	0.96	0.96
Purity %	77.67	85.37	87.30	89.32	76.50	88.04	86.38	89.25	80.48	89.92	91.68	90.65
Fibre %	9.87	10.32	12.85	11.97	11.02	11.01	11.44	11.56	10.70	12.33	11.05	11.88
C. C. S. %	8.06	10.21	11.53	12.79	7.80	10.96	12.05	12.88	9.24	12.05	13.49	13.52
C. C. S. per acre at harvest in tons		5.85				4.55				3.17		

The data revealed that the ratoons matured much earlier and are also richer in juice quality than plant crop. It can be seen that right from November to harvest, the second ratoon crop maintains the highest commercial cane sugar. But the C.C.S. per acre is lowest as compared with plant and first ratoon crops. Hence, on economic grounds, ratooning beyond once should be discouraged.

TABLE IX

EFFECT OF NITROGEN AND PHOSPHORIC ACID ON JUICE QUALITY Co. 419

Particulars	100 lbs. nitrogen per acre						150 lbs. nitrogen per acre						200 lbs. nitrogen per acre					
	Plant		1st Ratoon		2nd Ratoon		Plant		1st Ratoon		2nd Ratoon		Plant		1st Ratoon		2nd Rartoon	
	*S	P	S	P	S	P	S	P	S	P	S	P	S	P	S	P	S	P
November	14.26	83.73	14.25	83.98	15.56	84.81	13.93	82.90	14.55	86.09	14.63	85.15	13.13	82.07	14.09	84.04	14.20	83.94
December	16.16	87.80	16.08	84.90	16.39	87.99	15.19	85.51	16.03	85.28	15.38	83.06	15.57	86.49	15.04	82.09	15.41	84.01
January	17.04	89.29	16.90	88.75	18.29	90.64	17.78	88.09	16.45	86.75	17.55	90.58	16.91	88.54	17.25	88.77	18.36	91.58
February	17.71	88.29	18.46	90.34	18.80	90.80	17.69	98.34	17.92	88.71	17.30	88.23	16.43	86.86	18.08	90.81	18.43	90.19
	0 lb. P_2O_5 per acre						50 lbs. P_2O_5 per acre						100 lbs. P_2O_5 per acre					
November	13.56	82.13	14.74	84.03	15.10	84.03	13.84	83.15	13.86	18.14	14.56	83.70	13.82	83.78	17.63	85.63	18.06	85.40
December	15.31	85.91	15.90	84.32	15.41	85.54	15.09	86.41	15.49	84.06	15.68	84.26	15.93	87.49	15.83	84.48	16.08	85.26
January	17.70	88.87	17.28	89.31	17.90	90.48	16.72	88.30	16.39	85.46	16.94	89.50	17.31	88.75	17.94	89.50	18.20	91.82
February	17.18	87.65	18.66	90.41	18.05	89.51	17.54	88.03	18.42	90.15	18.32	89.42	17.12	87.91	17.38	89.30	18.16	89.71

*S=Sucrose and P=Purity

Increased doses of nitrogen reduced the sucrose content of the juice in plant crop while in first and second ratoons there was no such marked reduction. Phosphate did not show any influence on juice quality in any of the crops. The differences in quality of juice between 100 and 150 lbs. nitrogen treatments were not so wide as between 100 and 200 lbs. nitrogen treatments.

Average length and weight of millable canes and average number of canes per plot were generally more in plots irrigated once in 12 days than in plots that received irrigation once in 24 days irrespective of form of manure.

By way of irrigations and rainfall, plots irrigated once in 12 days received about 48.5 acre inches and yielded on an average 36 tons of cane per acre within a period of ten months, whereas plots irrigated once in 24 days received about 44 acre inches inclusive of rainfall and yielded about 30 tons of cane per acre. (Rainfall 35.83 inches)

(*ii*) Soil moisture estimations were conducted at two depths of soil, i.e., 0—6″ and 6″—12″ from all the treatments a day prior to irrigation. The data are presented below :—

TABLE XI

PERCENT SOIL MOISTURE AT DIFFERENT DEPTHS (1953-54)

Particulars	Irrigation once in 12 days			Irrigation once in 24 days		
	Ammonium sulphate	Ground-nut cake	Mixture	Ammonium sulphate	Ground-nut cake	Mixture
(i) 0—6″ depth						
From March to May	9.90	8.98	8.19	8.13	7.98	7.86
,, June to Nov.	14.85	14.61	15.61	12.30	13.85	13.16
,, Dec. to harvest	10.56	9.98	10.38	8.96	9.17	10.13
(ii) 6″—12″ depth						
From March to May	10.68	10.23	11.17	9.63	8.13	8.05
,, June to Nov.	14.64	14.46	14.75	13.95	14.24	14.23
,, Dec. to harvest	9.87	10.15	9.37	8.93	9.02	8.15

The range of soil moisture at 0—6″ depth varied between 8 to 9 percent in 12 day treatments and 7 to 8 percent in the 24 day treatments during summer months. On an average about 2% increase in soil moisture was recorded by 12 day irrigation treatment as compared to 24 day treatment during the period June to November. At lower depths, i.e., 6″—12″, differences in soil moisture between the two intervals of irrigation were not perceptible.

III. *Yield of Cane.* The details of cane yields per acre under different treatments along with calculated C.C.S. in tons per acre are given below :

TABLE XII

YIELD DATA Co. 419 (1953-54)

Particulars	Irrigaion once in 12 days			Irrigation once in 24 days			Mean	
	Ammonium Sulphate	Ground nut cake	Mixture	Ammonium Sulphate	Ground nut cake	Mixture	Irrigation Once in 12 days	Once in 24 days
Yield of cane in tons per acre	36.45	32.91	35.78	29.73	28.62	32.16	35.05	30.17
Calculated C.C.S. per acre in tons	2.77	2.72	3.57	2.31	2.48	2.70	3.02	2.50
Total quantity of water used in acre inches	48.43	48.43	48.84	44.54	44.00	44.27	48.56	44.20
Number of irrigations given	15	15	15	8	8	8	15	8
S.E. for Major treatments		1.66						
S.E. for Minor treatments		1.19		Z test not satisfied.				

The data indicate that the yield differences between irrigation treatments are marked, the 12 days interval recording higher cane yields per acre than 24 days interval. Yield differences due to manures were more pronounced in 12 day interval than in 24 day interval. In the case of ammonium sulphate, the difference in yield between the 12 and 24 day irrigation treatments was greater, compared to mixture and groundnut cake, indicating that sulphate of ammonia was better utilized with frequent irrigations. C.C.S. in tons per acre showed that they were in general higher in plots irrigated once in 12 days than those that received water once in 24 days and the application of mixture seems to be better in the case of 24 days irrigation interval compared to sulphate of ammonia and groundnut cake.

(iv) *Juice Quality* : The results of chemical analysis of juice from the different treatments are furnished below :

TABLE XIII

RESULTS OF CHEMICAL ANALYSIS OF JUICES Co. 419 (1953-54)

Particulars	Ammonium Sulphate		Ground nut cake		Mixture	
	Sucrose %	Purity	Sucrose %	Purity	Sucrose %	Purity
Irrigation once in 12 days						
November	8.74	70.55	9.05	72.18	9.33	72.97
December	11.68	75.28	12.52	76.05	12.82	77.22
Irrigation once in 24 days						
November	8.57	70.49	8.51	68.41	8.46	69.54
December	11.98	76.94	12.80	79.96	12.40	80.77

Practically there was no difference in respect of juice quality between the two irrigation treatments. Among the manurial treatments, plots manured with ammonium sulphate have shown slightly lower sucrose content in their juices than the other two treatments.

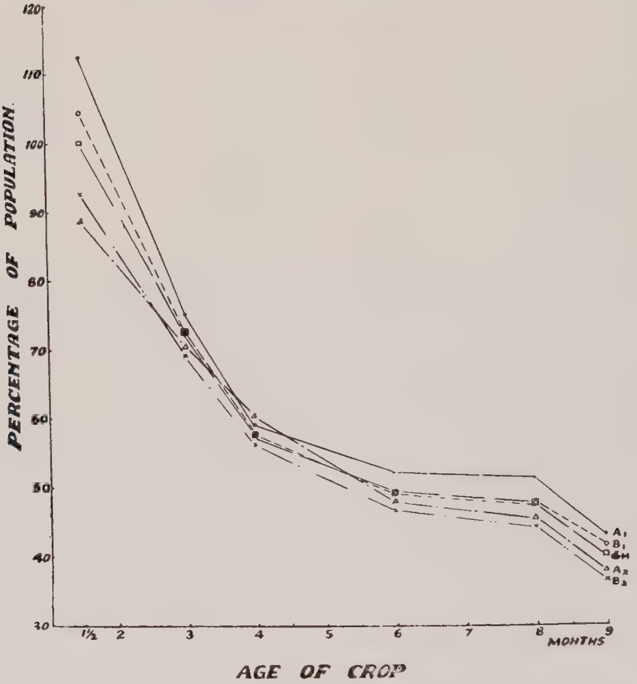
TIME OF APPLICATION AND FORM OF MANURE

(*i*) *Population.* Population counts recorded at periodical intervals are presented in Table XIV and Fig. 3.

FIG 3

POPULATION AT DIFFERENT STAGES OF CROP GROWTH

CO. 419 RATOON



(*ii*) *Sheath Moisture*. Sheath moisture was estimated by drawing random samples of third leaf sheaths from all treatments at different stages of crop growth, to study its relationship with juice quality. The data are given below :

TABLE XV

PERCENTAGE OF SHEATH MOISTURE

Treatments	Age at Sampling.			
	4th month	6th month	8th month	9th month at harvest
A_1	83.28	82.80	79.98	77.66
A_2	84.00	84.86	80.16	81.04
B_1	84.12	83.60	80.03	78.31
B_2	84.62	83.60	81.78	78.27

TABLE XIV

POPULATION PER ACRE AT DIFFERENT STAGES OF CROP GROWTH

DATE OF STARTING OF RATOON 16-3-54. Co. 419

Particulars	Treatments					As percentage				
	A_1	A_2	B_1	B_2	General mean	A_1	A_2	B_1	B_2	General mean
At 1½ months age (April)	93,440	73,800	86,320	76,533	82,523	113.22	89.43	104.60	92.74	100
At 3 months age (June)	61,987	58,093	59,707	57,453	59,301	75.11	70.39	72.11	69.62	71.87
At 4 months age (July)	48,853	49,453	48,267	46,053	48,159	59.20	59.92	58.49	55.80	58.35
At 6 months age (Sep.)	43,093	39,853	39,653	38,893	40,373	52.22	48.29	48.05	47.13	48.92
At 8 months age (Nov.)	40,080	35,540	37,494	35,120	37,059	48.57	43.06	45.43	42.55	44.91
At harvest end of Decem.	35,253	31,240	34,253	30,786	32,883	42.72	37.85	41.51	37.31	39.84

Early completion of fertilization had induced profuse tillering with over 40% of them surviving till harvest, whereas under delayed application of concentrates, tillering was less and at harvest the cane shoots formed were only 38% of the general mean. In spite of profuse tillering in the early stages of crop growth, there had been casualties upto 60% which can be attributed to self shading consequent on over crowding.

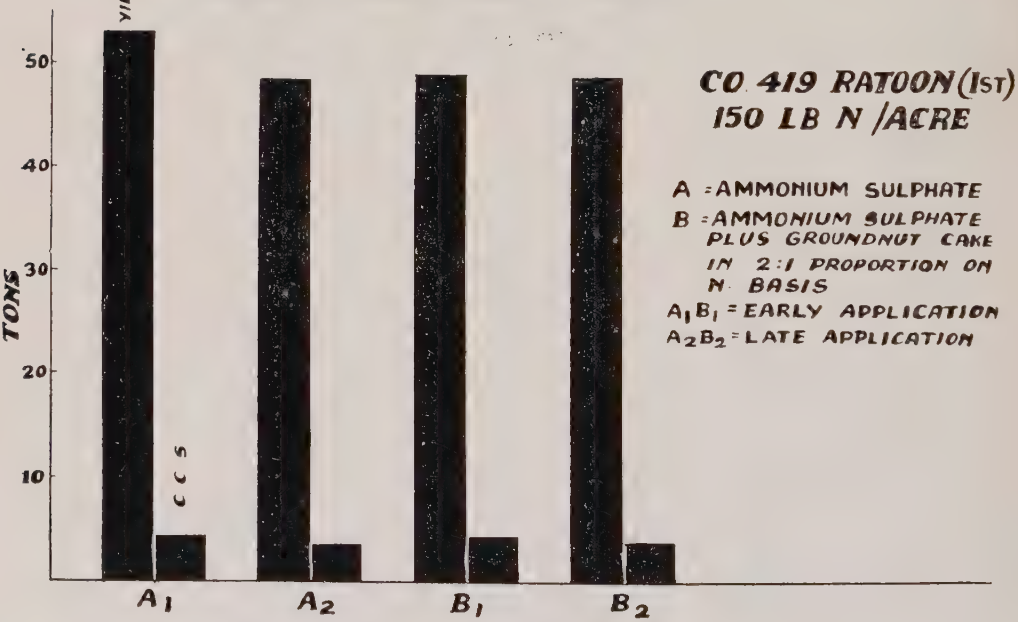
The figures indicated that the sheath moisture levels tend to decrease with the age of the crop. This was more marked in early application series compared to late application of manures. The accumulation of sucrose is more pronounced in the early application of ammonium sulphate compared to late application of the same, which has bearing on the sheath moisture percentage at harvest. When the manure was applied as an inorganic-organic mixture, early application showed better sucrose% than late application when the crop was nine months old though the differences in sheath moisture percentages were not perceptible.

(iii) *Arrowing.* Arrowing was practically nil in all the treatments. This indicates the supressing effect of 150 pounds nitrogen dose on ratoon crop when compared with 100 pounds nitrogen to ratoon crop.

(iv) *Yield Data.* The crop was harvested when nine months old. The data gathered at harvest is furnished below (Fig. 4).

FIG. 4

YIELD AND C.C.S. /ACRE



Late application of concentrates resulted in better cane development as is seen from the average length and individual cane weight. But in spite of this apparent improvement in individual cane weights, the yield per acre is observed to be lower under these treatments which can only be explained by the lower number of millable stalks at harvest. Thus early manuring increased population which had direct bearing on the final cane yields. Completion of fertilization within 45 days with ammonium sulphate has recorded the highest yield. There is no difference practically in yields in the case of inorganic-organic manure mixture with time of application. The C.C.S. per acre tends to be in favour of early application of manure irrespective of its form in spite of difference in cane yields due to the form of manure.

TABLE XVI

Co. 419

Treatment	Population at harves t	Average length of millable cane in inches	Average No. of internodes	Average girth in inches	Average weight of individual cane in lbs.	Acre yield in tons	C.C.S. Per acre in tons
A_1	35,253	126.6	24	1.07	3.37	53.00	4.47
A_2	31,240	131.1	26	1.06	3.49	48.70	3.74
B_1	34,253	121.5	23	1.10	3.21	49.05	4.46
B_2	30,786	132.6	26	1.10	3.55	48.80	4.08

S.E. for cane yields...2.2.
'Z' test not satisfied.

JUICE QUALITY AND C.C.S. PERCENTAGE

The juice analysis data for different months from December to March of the different treatments are given in Table XVII and Fig. 5

TABLE XVII

JUICE QUALITY Co. 419

Month	Treatments	Brix	Sucrose	Purity	C.C.S.%
December	A_1	16.48	12.75	76.80	8.44
	A_2	15.78	11.80	74.79	7.67
	B_1	16.28	13.30	78.89	9.08
	B_2	16.80	12.76	78.37	8.37
January	A_1	19.52	16.61	85.09	11.58
	A_2	17.68	14.45	81.73	9.67
	B_1	19.28	16.44	85.27	11.47
	B_2	17.52	14.42	82.13	9.87
February	A_1	20.89	18.52	88.65	13.16
	A_2	18.78	17.97	95.68	13.23
	B_1	20.69	18.45	89.17	13.16
	B_2	20.49	18.50	90.51	13.27
March	A_1	20.58	17.60	85.51	12.31
	A_2	20.08	17.49	87.06	12.34
	B_1	20.89	18.18	86.96	12.07
	B_2	19.96	17.43	87.30	12.21

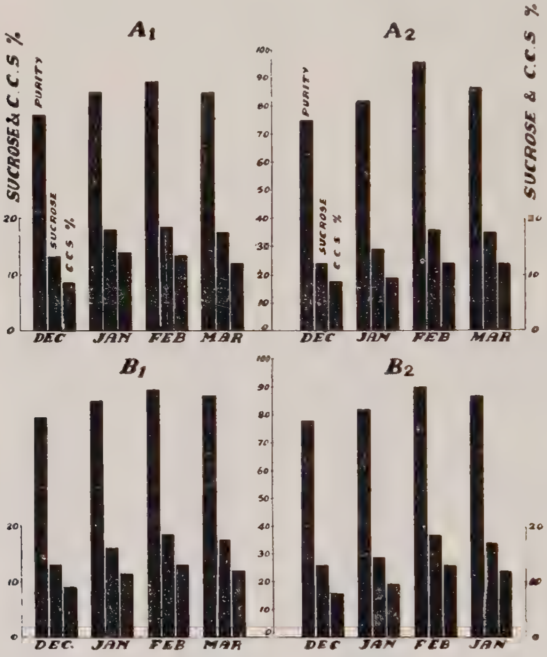
From the data presented above the following are the indications:—

1. When the manure is applied in the form of inorganic fertilizer alone the depression in juice quality is evident when harvested in December. This

difference is more pronounced with late application of manure.

2. In the case of application as mixture, the juice quality is superior compared to inorganic fertilization irrespective of time of application in the month of December.

FIG 5
JUICE QUALITY - CO 419 RATOON (1st)
150 LB N/ACRE



3. The juice quality in the month of January and February is decidedly richer in case of early manuring than late manuring irrespective of form of manure.

4. In the month of February, when the crop is eleven months old, there is perceptible difference in sucrose% in the case of early and late application of ammonium sulphate but whereas in the case of mixture of inorganic—organic manure, there is no difference in juice quality with time of application.

SUMMARY AND CONCLUSIONS

Studies on sugarcane ratoons of Co. 419 were carried out at Sugarcane Research Station, Anakapalle with a view to find out the probable causes for their low yields. The following are the salient features :—

1. The yield of cane and sugar per acre was found to be higher for the plant crop than the ratoons, the second ratoon recording the lowest values,

2. The yield of first ratoon crop could be raised considerably by increased application of nitrogen (150 lbs.) but the yield of second ratoon could not be raised upto the level of plant or first ratoon crop with increased nitrogen.

3. Ratoons matured earlier and recorded better juice quality than plant crop. They showed lower hydration in plant tissue compared to plant crop. Increased doses of nitrogen reduced the sucrose content of the juices in plant crop while in ratoons there was not much reduction.

4. Arrowing in ratoons could be suppressed with increased application of nitrogen, i.., 150 lbs. N per acre.

5. Phosphate application did not show any improvement in quality of juice or yield of cane in plant crop. In the case of second ratoons, however there was a tendency for increased yields with 50 lbs. $P_2 0_5$.

6. The nitrogen status of plant crop was of higher order than the ratoons. The over all nutrition status in respect of N, P and K was lowest for the second ratoon. Correspondingly the nitrate and total nitrogen in the soil also appeared to be lowest in the second ratoon.

7. The yield of ratoon cane was more under 12 days irrigation interval than with 24 days interval.

8. Difference in yields due to manures was more pronounced in closer interval of irrigation than wider interval of irrigation.

9. Ammonium sulphate was better utilized with frequent irrigations.

10. Application of mixture of manures seemed better with longer intervals of irrigation.

11. In juice quality there was no difference practically between two irrigation treatments, where as with the form of manure ammonium sulphate showed slightly lower sucrose content in the juice compared to other treatments.

12. In respect of time of manuring it was found that completion of fertilization within 45 days gave better yields compared to completion of fertilization within 90 days for first ratoon crop.

13. Application of ammonium sulphate alone to supply 150 lbs. N within 45 days recorded the highest yield.

14. With regard to quality of juice application of inorganic—organic mixture was found better in December when the crop was nine months old. When the crop was eleven months old the difference in juice quality due to form of manure were evened out but the differences due to time of application were pronounced.

15. The data tends to show that the manuring of ratoons with 150 lbs. N per acre should be completed within 45 days from the date of starting of the ratooning and the crop should be harvested at the age of eleven months to have better yield and C.C.S. per acre.

Considering the above results, it appears reasonable to state that the lower yields of ratoons as compared to plant crops is due to a greater need for nitrogenous manuring and a lower hydration status. With higher N doses and irrigations at frequent intervals the yields of ratoons can be pulled up. The possibility of phosphate being a limiting factor has been indicated.

ACKNOWLEDGEMENTS

Our thanks are due to Indian Central Sugarcane Committee, New Delhi for partly financing the Sugarcane Research Scheme at Anakapalle. We are also thankful to the officers and assistants working in different sections of this Station for the help rendered by them in connection with these studies.

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DISCUSSION

Mr. C.N. Agarwal wanted to know the reason behind ratoon yields in South Africa being higher than yield of the parent crop. Mr. Mohan Rao replied that he was not aware of the facts. Mr. Harbans Singh observed that ratoons have not shown any improvement with nitrogen applications and that nitrogen might not be the limiting factor, the stand of the cane being possibly responsible as observed in Louisiana. Mr. Mohan Rao replied that increase in yield with higher nitrogen had been shown, earlier application of nitrogen being however necessary.

In the absence of the author, Dr. Tisdale presented the following paper.

Paper

AGRONOMIC PRACTICES INFLUENCE STUBBLE DETERIORATION OF SUGARCANE

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And
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The term "stubble crop" is used in the United States to refer to the growth of sugarcane produced from stubbles of the previous crop. It is synonymous with the term "ratoon crop" commonly used in tropical countries. Failure of the stubble pieces to produce sufficient vigorous shoots for the succeeding crop is termed "stubble deterioration." This term is synonymous with another term, perhaps of more general use, "stand failure".

Extensive stubble deterioration for many years has been an important problem in the "Sugar Belt" of Louisiana. Varieties such as D. 74, P.O.J. 234, P.O.J. 213, Co. 290, C.P. 28-19, C.P. 28-11, and numerous other C.P. varieties highly susceptible to damage from diseases and environmental factors responsible for stubble deterioration have been replaced by others more resistant to injury. The general use of varieties susceptible to the mosaic disease and the resultant stubble deterioration during the early 1920's contributed to the important (almost fatal) decline of the sugar industry in Louisiana. Recovery of the industry to its present production level has been brought about with a succession of varieties resistant to diseases and severe stubble deterioration.

In sirup-producing areas of southern United States (Mississippi, Alabama and Georgia) stand failures were sometimes so serious that the practice of growing stubble crops was almost completely abandoned. Farmers in those areas adopted the plan of digging seed cane (including the rhizome and old root system with the stalk), storing it during the winter months, and planting it in the spring of the following year. Thus each crop was grown from planted cane. This was an expensive practice. The advent of new, vigorous, prolific, hardy varieties such as C.P. 29-116 and C.P. 36-111 during recent years has encouraged the general abandonment of the latter practice and has increased interest in the more economical procedure of growing stubble crops.

Stubble deterioration is recognized in all sugarcane-growing areas as a complex problem, and has been considered by several investigators as being associated with the reaction of the plant to pathological and physiological phases of the environment which reduce the efficiency of the roots and rhizomes[1] of the stubbles in producing plants for the succeeding crops. Also, it has been recognized that factors which cause stubble deterioration may not be the same in different years, or in different fields, or in different varieties, or under different cultural conditions.

Abbott (1) in considering the pathological and physiological phases of stubble deterioration states : "Stubble deterioration is sometimes looked upon as a separate disease, although with many varieties it results from the combined effects of red rot, root rot, and mosaic. In some varieties, of course, it is principally physiologic in nature... To some extent it affects the yields of all of the commercial varieties." Sartoris (10) found that the deterioration of early-cut stubbles in Louisiana was due to several factors and that ". . some are pathological, brought about by the activity of fungi and bacteria on the roots and rhizomes, and some are physiological, dependent upon the behaviour of the sugarcane plant. It is probable that the physiological factors are more important." Edgerton, Tims, and Mills (3,4,5) found that any factor which may affect the stubble pieces or the young shoots which develop from them is important in stubble deterioration. They discussed the responses of various sugarcane varieties to the whole complex of factors involved, including temperature, aeration and drainage, maturity of cane, time of cutting, the red rot fungus and other fungi, varietal resistance, stubble shaving, and condition of stubble roots. The recently discovered ratoon stunting disease (2,7,8) also contributes to stubble deterioration in most commercial varieties.

The normal function of the stubble pieces in producing new plants depends, at first, upon the root system of the previous crop. Gibbons (6) found that stubble roots function similarly to seed-piece roots of plant cane in supplying the young shoots with moisture until primary roots are formed. Van Dillewijn (15) found that the roots of the cane plant remain active for a considerable period after the crop is harvested.

Available plant food in the soil has been found to influence stubble crops of sugarcane. According to Stubbs (13), ". . the right manure not only shows itself in the increased tonnage of cane and yield of sugar, but in the increased vitality of the succeeding stubble." Stokes and Ashley (12) found that increased applications of up to 60 pounds of nitrogen per acre increased stubble stands and yields of cane and sirup per acre.

Suitable experimental data are not available to measure accurately the effect of each contributing factor or the interaction of the several factors thought to influence the extent and importance of stubble deterioration. There may be factors, or combinations of factors, other than those mentioned above involved in this complex problem.

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[1] Rhizome as used in this paper refers to the rootstock or underground portion of the stem remaining after the stalk is cut, during the harvesting operations, near the surface of the soil.

This paper offers a condensed summary of information secured during a period of 5 years to evaluate the influence of different fertility levels and dates of harvest on stubble deterioration in Mississippi.

MATERIALS AND METHODS

Suitable data for evaluating 4 fertility levels and 4 dates of harvest were obtained from 18 field experiments conducted on two soil types at two locations during the period 1947-1951. The variety C.P. 29-116 was used in all of the experiments.

A uniform application of 27 pounds of P_2O_5 and 13 pounds of K_2O was applied to all fertility levels in each experiment. Variations in fertility levels in each experiment comprised a check (no nitrogen) and applications at the rate of 20, 40, and 60 pounds of nitrogen per acre. Each fertility treatment was replicated 4 times in 4-row plots of 1/50th acre. These plots were arranged in a Latin-square experimental design.

Each fertilizer plot was divided into 4 sub-plots. Four dates of harvest (October 15, October 29, November 12, and November 26) were superimposed on the sub-plots. The sub-plots were 1/200th acre in size, and each date of harvest was replicated 16 times in each experiment. Each experiment was grown as plant cane, first-year stubble, and second-year stubble to measure the accumulative influence of the fertility levels and the dates of harvest on stubble deterioration.

Ruston fine sandy loam soil (14), characterized by good drainage, medium to low fertility, and subject to damage from erosion, was used for all tests at the South Mississippi Branch Station, Poplarville, Mississippi. A moderately well drained Ochlockonee very fine sandy loam soil (14) of medium to high natural fertility, located near a creek, was used for all tests conducted at the U.S. Sugar Crops Field Station, Meridian, Mississippi.

Data from the tests used to evaluate the effects of different fertility levels and different dates of harvest on stubble deterioration comprised stand counts, stalk weights, stored plant food in the stubble pieces, Brix, sucrose, yield of cane per acre, and yield of sirup per ton of cane and per acre.

Stand counts were made in June of both the main stalks and tillers (suckers). These counts included the total population of each plot. Yield of cane per acre was obtained at the time of harvest by weighing the stripped stalks from each plot to the nearest pound. Stripped stalks, as used in this paper, refers to stalks free of leaves and tops.

After the cane was weighed, field samples were selected from each plot. Each field sample consisted of 20 stalks selected at random throughout the plot. A special effort was made to choose stalks at random by selecting two at 10 regular intervals throughout the length of the plot. Field samples were weighed to the nearest tenth of a pound, and the average weight per stalk was calculated from these data.

Samples were crushed in a 3-roller mill set to produce approximately 55 per cent extraction with C.P. 29-116. The juice obtained was stirred thoroughly; and a portion of it, approximately one pint, was selected for juice analyses, which in most cases consisted of Brix readings. In some cases, sucrose analyses were also conducted. Brix readings were made with a Brix hydrometer standardized at 20°C. Horne's dry lead method of sucrose analysis (11) was used in each case.

A portion of the juice from each sample of each treatment, usually about 10 pounds, was composited and used for a sirup test. Sirup tests consisted of clarifying 40 pounds of juice and heating and evaporating it to a density of 72 degrees Brix. Data obtained from the sirup tests included the weight of the finished sirup and the weight of the skimmings.

The weight of sirup from each test was used to calculate the percent of sirup produced from 40 pounds of juice. This value (percent of sirup) and the average extraction obtained were used to calculate yields of sirup per ton of cane for each treatment. Yields of sirup per acre were obtained by multiplying the yield of sirup per ton of cane by the yield of cane per acre.

In order to determine the amount of stored plant food in the stubble pieces, 6 to 10 stubbles were dug from each plot of the second-year stubble tests at the time of harvest and later at intervals up to January of the following year. These stubbles were washed throroughly to remove all soil, allowed to dry, and then crushed in a 3-roller mill. Juice extracted from the stubbles was then analyzed for Brix and sucrose, following the method described above for the analysis of juice from the stalks.

RESULTS AND DISCUSSION

The measurable influence of 4 fertility levels (0, 20, 40, and 60 pounds of nitrogen per acre) and 4 dates of harvest (October 15, October 29, November 12, and November 26) on stubble deterioration was determined by a statistical analysis of data from 6 plant cane, 6 first-year stubble, and 6 second-year stubble experiments with C.P. 29-116 in Mississippi. In each group of experiments (plant cane, first-year stubble, and second-year stubble), 3 were conducted at Poplarville and 3 at Meridian. The data obtained included yields of cane per acre, Brix, and yield of sirup per ton of cane and per acre from all tests, stand counts from stubble experiments, stalk weights from plant cane and stubble experiments, and the amount of plant food stored in stubble pieces of second-year stubble experiments.

Data obtained from the 18 experiments furnished two types of information on the influence of different fertility levels and harvesting dates on sugarcane production: (1) The effects of each treatment on yield, components of yield, and other characteristics in the current crop (plant cane, first-year stubble, or second. year stubble); and (2) a measure of the influence of each treatment on stubble deterioration. This paper deals primarily with the latter, and the discussion will be limited principally to comments about the influence of different fertility levels and dates of harvest on stubble deterioration. A brief evaluation of the different components of yield studied is also furnished.

To secure information about the effects of the treatments on stubble deterioration, it was necessary first to measure their influence on the plant cane crop. Information was then secured to evaluate the accumulative effect on the succeeding first-year stubble and second-year stubble crops. An estimate of the influence of different fertility levels and different dates of harvest on stubble deterioration was determined by deducting their effect on the plant cane crop from their cumulative effect on the first-year and second-year stubble crops. Harvesting dates in stubble crops were the same as in plant cane. Stubble deterioration was measured principally in yields of cane and sirup per acre, number of stalks per acre, average weight per stalk, and the Brix and sucrose content of the stubble pieces.

EFFECTS OF FERTILIZER TREATMENTS ON STUBBLE DETERIORATION

Fertilizer treatments used in this study did not influence stubble deterioration to a significant extent in any of the experiments. The greatest numerical influence, though not highly significant statistically, is shown by mean yields of cane per acre in Table I.

TABLE I

INFLUENCE OF FERTILIZER TREATMENTS ON TONS OF CANE PER ACRE

	Plant cane*		First-year stubble*		Second-year stubble*	
Fertilizer Treatments**	Tons	Percent of "0" nitrogen treatment	Tons	Percent of "0" nitrogen treatment	Tons	Percent of "0" nitrogen treatment
0-27-13	24.93	100	22.15	100	15.45	100
20-27-13	27.60	111	24.65	111	16.74	108
40-27-13	28.45	114	27.65	125	18.90	122
60-27-13	28.69	115	28.44	128	18.49	120
L.S.D. 0.05	1.77		1.79		1.85	
0.01	2.37		2.40		2.48	

*Means of 6 experiments—3 at Meridian and 3 at Poplarville.
**Pounds of N, P_2O_5, and K_2O, respectively, applied each year.

A comparison of yields from first-year and second-year stubble experiments with yields from plant cane experiments in Table I shows that 20 pounds of nitrogen did not influence stubble deterioration. The percent gain from 40 pounds of nitrogen as compared to "0" nitrogen in first-year and second-year stubble experiments was 11 and 8 percent respectively higher than in plant cane. Also gains from 60 pounds of nitrogen in first-year and second-year stubble experiments were higher than in plant cane by 13 and 5 percent respectively. Though the influence was not highly significant statistically, applications of 40 and of 60 pounds of nitrogen per acre had a tendency to reduce stubble deterioration in first-year and second-year stubble crops as shown by relatively higher gains than from the same treatments in plant cane.

The fertilizer treatments 0, 20, 40, and 60 pounds of nitrogen per acre had no significant influence on the Brix of the juice or the yield of sirup per ton of cane in the plant cane, first-year stubble, or second-year stubble crops. As previously indicated, the yield of sirup per acre is the product of yield of sirup per ton of cane by yield of cane per acre. Thus, since the fertilizer treatments did not have an important influence (numerically or statistically) on yields of sirup per ton of cane, their effects on yields of sirup per acre were approximately the same as described above for tons of cane per acre.

There was no significant difference between the number of stalks per acre from the different fertilizer treatments. In most experiments there were as many stalks in "0" nitrogen treatments as where 60 pounds of nitrogen per acre was applied. The small effect of the 4 fertility levels on stubble deterioration was not reflected in the number of stalks per acre.

The average weight per stalk for each fertility level, 0, 20, 40, and 60 pounds of nitrogen per acre, was also approximately the same in the plant cane and first-year and second-year stubble crops. Relatively small effects of the different fertility levels on stubble deterioration could not be measured in the average weight per stalk.

Brix and sucrose content of stubble pieces of January 2 for the 4 fertility levels did not differ significantly in plant cane and first-year and second-year stubble crops. The numerical indication, that 40 and 60 pounds of nitrogen decreased stubble deterioration, as shown by relatively higher gains in first and second-year stubble crops described for tons of cane and indicated for gallons of sirup per acre, appears to represent the cumulative effect of small, statistically insignificant gains in two of the components of yield, number of stalks per acre, and the average weight per stalk.

INFLUENCE OF HARVESTING DATES ON STUBBLE DETERIORATION

The four harvesting dates October 15, October 29, November 12, and November 26 had an important influence on stubble deterioration as measured by their influence on tons of cane and gallons of sirup per acre, the number of stalks per acre, and the Brix and sucrose content of the stubble pieces. Harvesting dates also influenced the Brix of the juice extracted from the stalks and the yields of sirup per ton of cane during any crop year, but their effects on stubble deterioration were not reflected in these two characters.

Average yields of cane per acre in plant cane, first-year stubble, and second-year stubble experiments are shown in Table II.

TABLE II

INFLUENCE OF HARVESTING DATES ON TONS OF CANE PER ACRE

Harvesting dates		Plant cane*		First-year stubble*		Second-year stubble*	
		Tons	Percent of October 15 harvest	Tons	Percent of October 15 harvest	Tons	Percent of October 15 harvest
October	15	25.83	100	18.34	100	9.58	100
October	29	26.45	102	24.21	132	15.33	160
November	12	28.18	109	29.40	160	22.32	233
November	26	29.21	113	30.83	168	22.35	233
L.S.D.	0.05	1.30		1.46		1.30	
	0.01	1.72		1.92		1.76	

* Means of 6 experiments—3 at Meridian and 3 at Poplarville.

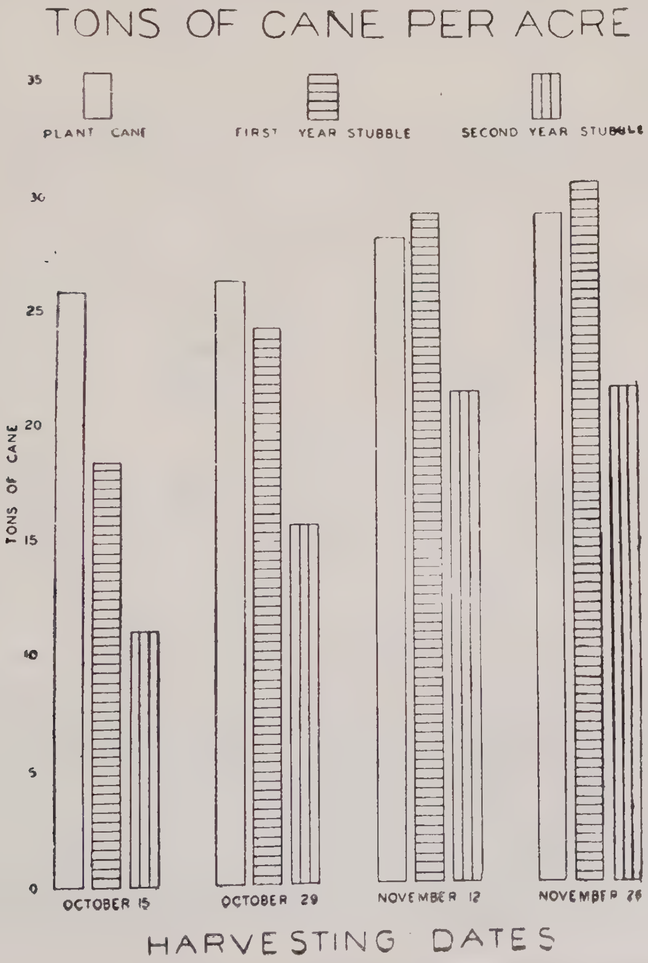

Figure 1. Graph showing the influence of harvesting dates on tons of cane per acre ; means of all tests.

In plant cane the yields of cane per acre on October 29, November 12, and November 26 exceeded the yield on October 15 by 2, 9, and 13 percent, respectively. These gains represent increased growth associated with delayed harvest. Increase in yields of cane per acre in the first-year stubble experiments (Table II) on October 29, November 12, and November 26 were 30, 51, and 55 percent respectively, greater than from the same dates of harvests in plant cane. The relative increase in yields from the last three harvests of the first-year stubble crop as compared to gains for the same dates of harvest in plant cane represents increased growth associated with delayed harvest during the current season plus the beneficial effect (decrease in stubble deterioration) of late harvests during the previous year. Also, in the second-year stubble experiments increases in yields on October 29, November 12, and November 26 above those on October 15 were 58, 124, and 120 percent respectively, greater than yields on the same dates in plant cane. These data, illustrated in Figure 1, show that a delay in harvesting the plant cane crop to October 29, November 12, and November 26 had a beneficial effect on yields of cane per acre in the first-year and second-year stubble crops. This beneficial effect represents a decrease in stubble deterioration associated with delayed harvests.

The average Brix on October 15, October 29, November 12, and November 26 for plant cane, first-year stubble, and second-year stubble experiments is shown in Table III.

TABLE III

INFLUENCE OF HARVESTING DATES ON DEGREES BRIX

Harvesting dates		Plant cane*		First-year stubble*		Second-year stubble*	
		Brix	Percent of October 15 harvest	Brix	Percent of October 15 harvest	Brix	Percent of October 15 harvest
October	15	14.29	100	14.81	100	14.28	100
October	29	15.27	107	15.60	105	15.82	111
November	12	15.45	108	16.19	109	16.15	113
November	26	16.36	114	16.43	111	15.53	109
L.S.D.	0.05	0.15		0.16		0.19	
	0.01	0.20		0.21		0.25	

* Means of 6 experiments—3 at Meridian and 3 at Poplarville.

In each experiment there was an increase in the Brix from October 15 to November 26. Average increases in Brix associated with delayed harvests in first-year and second-year stubble crops did not differ significantly from increases in plant cane. Effects of delayed harvest in plant cane on reducing stubble deterioration in the first-year and second-year stubble crops, shown in yield of cane per acre, could not be measured in the Brix of the juice extracted from the stalks.

Since the yield of sirup per ton of cane is highly correlated with the Brix of the juice, increases in yields on October 29, November 12, and November 26 as compared to October 15, shown in Table IV, were also approximately the same in plant cane, first-year stubble, and second-year stubble experiments.

TABLE IV

INFLUENCE OF HARVESTING DATES ON GALLONS OF SIRUP PER TON OF CANE

Harvesting dates		Plant cane* Gallons	Plant cane* Percent of October 15 harvest	First-year stubble* Gallons	First-year stubble* Percent of October 15 harvest	Second-year stubble* Gallons	Second-year stubble* Percent of October 15 harvest
October	15	17.8	100	18.0	100	17.1	100
October	29	19.0	107	19.2	107	19.3	113
November	12	19.4	109	19.7	109	19.5	114
November	26	20.4	115	20.0	111	18.9	111
L.S.D.	0.05	0.71		0.66		0.52	
	0.01	0.94		0.88		0.69	

*Means of 6 experiments—3 at Meridian and 3 at Poplarville.

There was a small numerical increase in the second-year stubble yields of sirup per ton of cane as compared to yields in plant cane and first-year stubble crops on October 29 and November 12, but the differences were not statistically significant. Reduction in stubble deterioration associated with delayed harvest could not be measured in yields of sirup per ton of cane.

Average yields of sirup per acre shown in Table V demonstrate, as described above for yields of cane per acre, that there was an increase in yields associated with delayed harvests in plant cane and first-year and second-year stubble experiments.

TABLE V

INFLUENCE OF HARVESTING DATES ON GALLONS OF SIRUP PER ACRE

Harvesting dates		Plant cane* Gallons	Plant cane* Percent of October 15 harvest	First-year stubble* Gallons	First-year stubble* Percent of October 15 harvest	Second-year stubble* Gallons	Second-year stubble* Percent of October 15 harvest
October	15	456	100	330	100	155	100
October	29	502	110	466	141	298	192
November	12	544	119	581	176	439	283
November	26	592	130	624	189	436	281
L.S.D.	0.05	36		88		73	
	0.01	48		116		98	

*Means of 6 experiments—3 at Meridian and 3 at Poplarville.

In plant cane the yields of sirup per acre on October 29, November 12, and November 26 exceeded the yield on October 15 by 10, 19, and 30 percent respectively. These relative increases in yield of sirup per acre were somewhat greater than observed in yields of cane per acre, because they reflect the additional benefit from delayed harvests associated with minor increases in yields of sirup per ton of cane. In the first-year stubble experiments increases in yield of sirup per acre on October 29, November 12, and November 26 as compared to October 15 were 31, 57 and 59 percent respectively, higher than in plant cane, illustrating again the beneficial effects from delayed harvests.

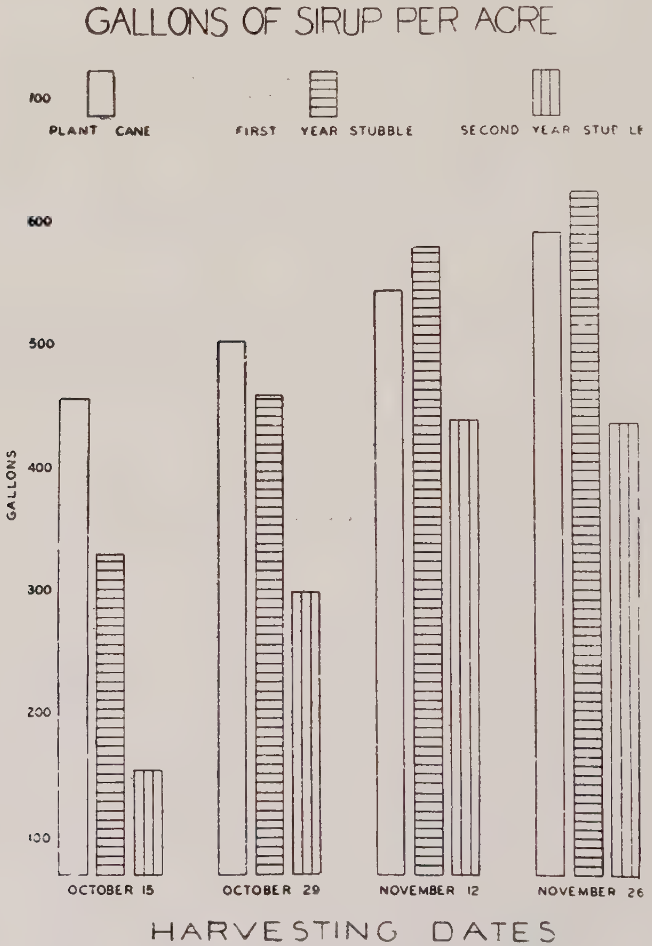

Figure 2. Graph showing the influence of harvesting dates on gallons of sirup per acre ; means of all tests.

The effects of delayed harvest in the second-year stubble experiments show that the yields on October 29, November 12, and November 26 were 82, 164, and 151 percent, respectively, higher than from the same dates of harvest in plant cane. These data, shown graphically in Figure 2, demonstrate, as described for tons of cane per acre, that delays in harvesting plant cane had a beneficial effect on yields of sirup per acre in first-year and second-year stubble crops.

The influence of harvesting dates on the number of stalks per acre is illustrated by second-year stubble stands in Figure 3 and representative first-year stubble data in Table VI.

TABLE VI

INFLUENCE OF HARVESTING DATES IN PLANT CANE ON THE NUMBER OF STALKS PER ACRE IN THE FIRST-YEAR STUBBLE CROP*

Harvesting dates (plant cane)		Number of stalks per acre (first-year stubble)
October	15	17,000
October	29	37,200
November	12	40,400
November	26	34,800
L.S.D.	0.05	4,750
	0.01	6,364

* First-year stubble experiment at Meridian.

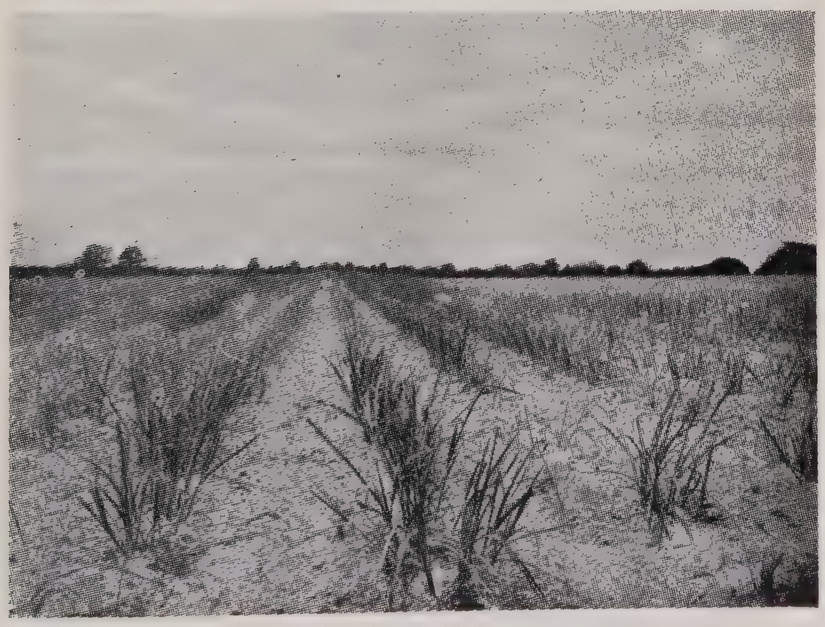

Figure 3.

A second-year stubble crop of sugarcane showing the effect of early harvest on the number of stalks per acre. The two rows on the left were harvested during the previous year on November 12 and the two on the right, on October 29.

These data show that the number of stalks per acre in the first-year stubble crop from the October 15 harvest of the preceding year was significantly lower than for the harvests on October 29, November 12, and November 26 by 54, 58, and 51 percent respectively. Also, the number of stalks from the harvest on November 26 was significantly lower (14 percent) than from the harvest on November 12. The number of stalks per acre from the November 12 harvest exceeded the number of stalks per acre from the October 15 and October 29 harvests by 58 and 8 percent respectively. Thus, the significant effect of the different dates of harvest on stubble deterioration described previously for tons of cane and gallons of sirup per acre is due in part to their influence on the number of stalks per acre.

It is of interest to consider briefly some of the possible explanations for the significantly lower number of stalks per acre in the first-year stubble crop from plant cane harvests on October 15 and November 26 as compared to November 12. In each experiment the top buds on the stubble pieces germinated immediately after the October 15 harvest. Shoots that developed from these buds were killed by frost in November. Stalks for the succeeding crop necessarily developed the following spring from the lower buds on the stubble pieces. Germination of the lower buds was slow because of their protected location in cool soil, resulting in a delayed stand and a minimum amount of tillering.

Freezing temperatures occurred during most seasons 3 to 4 weeks prior to the November 26 harvest. Sartoris (10) found that frozen cane in Georgia must be harvested immediately, or the next crop would have a poor stand. He did not suggest an explanation for this reaction. One of the possible explanations for this decline in number of stalks per acre from the November 26 harvest is that the mature buds on the upper part of the stubble pieces that remain dormant during the winter may germinate unusually early in the spring, resulting in the death of the young shoots by freezing temperatures that occur during February, March, and sometimes in early April. This explanation is based on the assumption that the more mature buds on the stubble pieces from the November 26 harvests have a tendency to germinate earlier than the slightly less mature buds from the November 12 harvest.

Another possible explanation of this decline in number of stalks per acre from the November 26 harvest is that the freezing temperatures prior to harvest may have caused the development of certain toxic substances that were translocated into the stubble pieces and that the presence of these toxic substances caused a failure of the normal development of shoots the following spring.

It is recognised that neither of these possible explanations for the decline in number of stalks per acre from November 26 harvest as compared to November 12 may be entirely correct. The real explanation, which can be determined only by adequate research on this phase of the subject may involve some of the factors from each of the possible explanations given or may be entirely different.

Harvesting dates had a significant influence on the average weight per stalk in plant cane and stubble experiments, as shown by typical data in Table VII.

TABLE VII

INFLUENCE OF HARVESTING DATES ON THE AVERAGE STALK WEIGHT*

Harvesting dates		Pounds per stalk	
		Plant cane	First-year stubble
October	15	1.43	1.84
October	29	1.66	1.45
November	12	1.66	1.82
November	26	1.71	1.97
L.S.D.	0.05	0.10	0.06
	0.01	0.14	0.08

*Means of 16 replications in tests at Meridian.

In plant cane the stalk weight on October 15 was significantly lower than on October 29, November 12, and November 26. There was no significant difference in the plant cane crop in stalk weight on October 29, November 12, and November 26. The lowest stalk weight in the first-year stubble crop on October 29 was significantly lower than on October 15, November 12, and November 26. Stalk weights on October 15 and November 12 were approximately the same and about 8 percent lower (significantly lower) than the stalk weight on November 26. The stalk weight on November 26 exceeded the stalk weight on October 29 by 26 percent. These data show that harvesting dates influenced the average stalk weight each year ; however, the increase from late harvests was no greater in the first-year stubble than in the plant cane crop. Thus, the effect of harvesting dates on stubble deterioration was not reflected significantly in the average weight per stalk.

The average Brix of juice extracted from stubble pieces of second-year stubble experiments on October 15, October 29, November 12, November 26, and January 2 is shown in Table VIII.

TABLE VIII

INFLUENCE OF HARVESTING DATES ON DEGREES BRIX IN SECOND-YEAR STUBBLE PIECES*

Harvesting dates		Dates of Analyses				
		October		November		January
		15	29	12	26	2
October	15	15.18	13.04	11.86	10.77	6.91
October	29		15.23	13.90	11.93	7.13
November	12			14.94	12.38	7.70
November	26				13.46	8.21
L. S. D.	0.05					0.21
	0.01					0.28

*Each figure is the mean of 10 analyses from a second-year stubble experiment at Meridian.

On January 2 the Brix of stubble pieces from the October 15 harvest was significantly lower than from harvests on October 29, November 12, and

November 26. Also, the Brix on January 2 from stubble pieces of the October 29 harvest was significantly lower by 7 and 13 percent than from harvest on November 12 and November 26, respectively. Again, the Brix from the November 12 harvest was 6 percent lower on January 2 than from the November 26 harvest.

There was a numerical decrease in the Brix of the stubble pieces from each time of harvest to January 2, regardless of the date of harvest. Also, there was a decrease in the Brix at the time of harvest when the harvesting date was delayed later than October 29. It appears that the physiological processes of the sugarcane plant decreased the Brix in the stubble pieces after October 29 whether the cane was standing or harvested. These processes depleted the Brix at a much faster rate after the cane was harvested. Thus, it is concluded that the influence of harvesting dates on stubble deterioration is reflected in a greater decrease during the dormant season in the Brix of stubble pieces of the early harvest than of the late harvests.

The percent sucrose in the juice extracted from second-year stubble pieces is shown in Table IX.

TABLE IX

INFLUENCE OF HARVESTING DATES ON SUCROSE IN SECOND-YEAR STUBBLE PIECES*

Harvesting dates		Dates of Analyses October 15	October 29	November 12	November 26	January 2
October	15	12.18	9.82	8.57	6.66	3.75
October	29		14.26	12.42	10.37	5.72
November	12			13.81	11.20	6.27
November	26				12.36	6.18
L.S.D.	0.05					0.89
	0.01					1.22

*Each figure is the mean of 10 analyses from a second-year stubble experiment at Meridian.

On January 2 the percent sucrose in the stubble pieces from the October 15 harvest was significantly lower than from the last 3 dates of harvest on October 29, November 12, and November 26. Though the sucrose content of the stubble pieces on January 2 from the October 29 harvest was numerically lower than from harvests on November 12 and November 26, the differences were not significant. The highest sucrose on January 2 was from stubbles of the November 12 harvest. There was no significant difference between the sucrose from the November 12 and November 26 harvests.

The sucrose in the stubble pieces at the time of harvest increased numerically from October 15 to October 29 but decreased gradually from October 29 to November 26. There was, as described previously for Brix, a numerical decrease in the sucrose content of the stubble pieces from the time of harvest to January 2, regardless of the date of harvest. Also, as indicated previously for Brix, it appears that physiological processes of the sugarcane plant caused decrease in sucrose content of the stubble pieces after October 29 whether the cane was harvested or left standing in the field. After the cane was harvested, these processes depleted the sucrose content of the stubble pieces at a faster rate. As shown previously for Brix, the influence of harvesting dates on stubble deterioration is indicated in a greater decrease in the sucrose content of stubble pieces of the early harvest than of the late harvests.

SUMMARY

1. The failure of stubble (ratoon) pieces to produce a satisfactory number of vigorous shoots for the succeeding crop is termed "stubble deterioration."

2. Information is furnished about the effect of 4 fertility levels and 4 dates of harvest on stubble deterioration.

3. An estimate of the influence of these two factors on stubble deterioration was obtained by deducting their effect individually on the plant cane from their cumulative effect in first-year and second-year stubble crops as reflected in yields of cane and sirup per acre, Brix, yields of sirup per ton of cane, number of stalks per acre, average weight per stalk, and the Brix and sucrose content of stubble pieces.

4. The 4 fertility levels 0, 20, 40 and 60 pounds of nitrogen per acre did not influence stubble deterioration to an important extent in any of the tests. Increases in yields from 20, 40 and 60 pounds of nitrogen over the check were approximately the same in plant cane and first-year and second-year stubble crops. Thus, the effects of the fertilizer treatments were primarily on the current crop rather than on stubble deterioration and yields of successive crops.

5. Four harvesting dates—October 15, October 29, November 12 and November 26—had an important influence on stubble deterioration as measured by their effects on tons of cane, gallons of sirup, and number of stalks per acre and the Brix and sucrose content of the stubble pieces. Though the harvesting dates influenced the Brix in the stalks and yields of sirup per ton of cane during any one crop season, the effects on stubble deterioration could not be measured by these characters ; because increases from late harvests in first-year and second-year stubble crops were the same as in plant cane.

6. The influence of harvesting dates was reflected significantly in one of the components of yield, the number of stalks per acre. Delays in harvest to October 29 and November 12 caused a significant increase in the number of stalks per acre as compared to the lowest number on October 15. A further delay in harvest to November 26 caused a decline in the number of stalks per acre

as compared to the November 12 harvest. The reason for this decline in number of stalks per acre on November 26 is not known. Two possible explanations are suggested.

7. Harvesting dates influenced stalk weight, another component of yield, in each crop. The lowest stalk weight in plant cane was from the first harvest on October 15, and the highest, from the last harvest on November 26. Also, in the first-year stubble crop the highest stalk weight was from the last harvest on November 26. Since the increase in stalk weight from the early to the late harvest in the first-year stubble crop was approximately the same as in plant cane, the effects of harvesting dates on stubble deterioration could not be measured by the weight per stalk.

8. The reserve food supply in the stubble pieces (Brix and sucrose) was influenced significantly by the harvesting date. Each delay in harvest from October 15 to November 26 caused an increase in Brix of the stubble pieces as measured on January 2 of the following year. A similar increase, though less significant, was shown in the sucrose on January 2 from the October 15 to November 26 harvest. Since increases in the reserve food supply in stubble pieces follow the same trend as increases in yield of cane and sirup per acre, it is concluded that the effects of harvesting dates on stubble deterioration are due largely to the reduction in reserve food supply in the stubble pieces from early harvests.

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In the absence of the authors the following paper was taken as read.

Paper

STUDIES IN PLANTING BUD, SHOOT AND SEEDLING SETTS OF SUGARCANE

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INTRODUCTION

Sugarcane is usually cultivated by planting triple bud setts, although shoot and seedling setts are sometimes used for gap-filling. In Java, the method of planting single shoot setts, called "Rayungans", is in vogue and Dillewijn reports that in pre-war time, more than half the acreage of commercially grown cane in that country was planted by this method. According to him, top cuttings, with three eye-buds each, and single shoots only 2/5th in number of buds, give practically the same yield of sugar per acre (2). In India, the "Rajoong" method of planting cane with double shoot setts is being successfully followed on submerged lands in Kolhapur since 1938; and it is believed that the cane obtained by this method is richer in sugar content than that obtained by the usual method of planting with triple bud setts (1). This belief is, however, not borne out by experimental evidence.

In the Bombay Deccan, the Adsali planting done between June-September period is found to be superior to later plantings in respect of both yield and sugar. It is also found that the earlier the planting in this period, the higher the yield of cane and sugar per acre (3). In some areas which are liable to be submerged under the river floods, it is not possible to adopt the usual method of planting triple bud setts in the months of June and July. This difficulty can be overcome by preparing shoot and seedling setts in this period, in flood-free lands and made ready for transplanting in August or September when the risk of flood is over.

At Ugar, about 40% of the cultivable land is subject to submersion in floods which cannot be planted in June and July.

It was, therefore, thought that a fundamental study of planting double and single shoot and seedling setts in comparison with triple bud setts, would be very useful and interesting. Experimental work was, therefore, started from the season 1950-51 and is being continued since then. The results of this work are presented and discussed in this paper.

MATERIALS AND METHODS

(*i*) *Soil.* The soil of the experimental plots was "B" type according to the Genetic Soil Survey of the Sugarcane Development Scheme, Padegaon, Bombay State and it has the following properties:—

1. Clay percent	60
2. Moisture holding capacity percent	40 to 50
3. Available P_2O_5 percent	<0.005
4. Lime reserve percent	.5 to 10
5. Available K_2O	0.02 to 0.06
6. pH value	8.5 to 9.0

(*ii*) *Climatic Conditions.* Ugarkhurd lies in the Belgaum District of the Bombay State. The annual average rainfall is 21.71 inches and the mean maximum and minimum temperatures are 9°F and 6°F respectively. The monthly variations in the rainfall and temperatures are given in Table I.

TABLE I

AVERAGE RAINFALL AND TEMPERATURE OF 5 YEARS

	Rainfall Inches	Rainy Days	Temperature Maximum °F	Temperature Minimum °F
June	2.95	9	106	71
July	3.84	16	93	70
August	1.75	10	91	70
September	4.19	8	89	71
October	5.51	12	95	69
November	0.18	1	92	64
December	Nil	—	89	59
January	Nil	—	91	61
February	Nil	—	97	69
March	0.51	2	103	72
April	0.87	3	107	75
May	1.68	5	106	74
Overall	21.71	66	96	69

(*iii*) *Kinds of Setts Tried.* (As per sketch)

(A) *Triple Bud Setts.* These were stalk cuttings with three eye-buds each, which are usually used for planting. Two controls of this kind were tried.

(a) the first one was planted (early) in the experimental plot when the setts were embedded in the nursery beds for making shoots and seedlings.

(b) the planting of the second control late (was) done when the transplantation of shoot and seedling setts was done in the experimental plots.

Sugarcane is cultivated on lift irrigation from the river Krishna.

(B) *Shoot Setts.* These were prepared by planting triple and double bud setts vertically in nursery beds, for making double and single shoot setts, respectively. The aerial buds which developed into shoots with four to five leaves were cut with the node portions within five to six weeks from planting. These setts had no sett roots.

(C) *Seedling Setts.* These were prepared by planting double and single bud setts horizontally in the nursery beds. The buds that developed into shoots with four to five leaves, were up-rooted for transplanting, within five to six weeks from planting. These setts had sett roots.

36000 buds as against 24000 shoots and seedlings of Co. 419 variety were planted horizontally on one side of the furrow per acre.

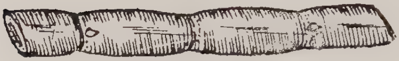
(*iv*) *Preparation of Shoot and Seedling setts.* Flat nursery beds of 25′ x 4′ were prepared after levelling the soil and fifteen pounds of F.Y.M. were applied to each bed, which was properly soaked with water before planting. Each bed supported 720 setts planted vertically and about 300 setts planted horizontally. Care was taken to embed the lower bud in the soil properly in the vertical planting of setts. Half a pound of sulphate of ammonia was applied in two doses to each bed—the first dose was applied with planting and the second one within two to three weeks from planting. Irrigation was given according to requirement.

(*v*) *Treatments.* The study is being done on statistical basis since 1951. In the first season, only five treatments were tried. One more treatment was added from the year 1952-53. Six treatments were replicated six times in a randomised fashion. The treatments were as under :—

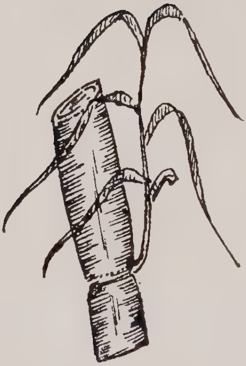
1. Triple Bud (Early)—Planting was done with the planting of nursery. (i.e. about 5 to 6 weeks earlier than other treatments.)
2. Triple Bud (Late)—Planting was done with the transplantation of Shoot and Seedling setts.
3. Double Shoot.
4. Single Shoot.
5. Double Seedling.
6. Single Seedling.

Germination, survival percentages, plant population and growth were recorded at regular intervals and the harvesting data and Mill Tests of each treatment were taken separately.

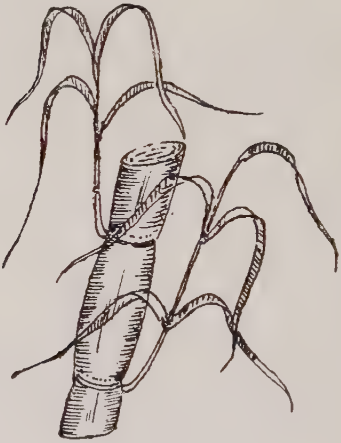
KINDS OF SETTS



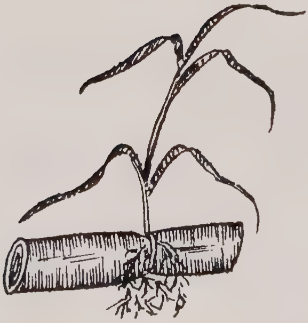
TRIPLE BUD



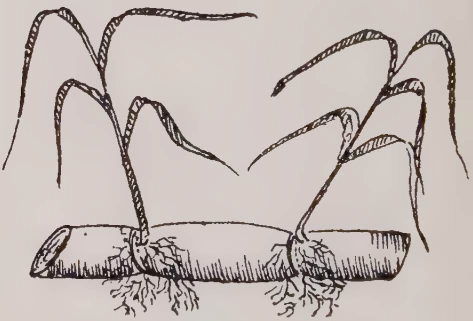
SINGLE SHOOT



DOUBLE SHOOT



SINGLE SEEDLING



DOUBLE SEEDLING

(*vi*) *Experimental Results and Discussion.* The stand counts taken between six to eight weeks after planting are given in Table II.

TABLE II

GERMINATION PERCENTAGES IN TRIPLE BUD SETTS IN THREE SEASONS

Kind of planting	Season 1951-52	1952-53	1953-54	Average
Triple bud (Early)	53.00	68.20	55.00	58.73
Triple bud (Late)	64.30	51.30	42.59	52.71
			Overall	55.73

It is seen that,

1. Early planting gave better germination than late planting in the June-September period.
2. With all the care taken in planting, over 40 percent buds failed to germinate due to some reason or the other.

SURVIVAL OF SHOOTS AND SEEDLINGS

In the first three seasons of the trial, no preplanting irrigation was given to shoot and seedling setts. Mortality of shoots was observed for two weeks after transplantation. The counts of survival which were recorded are given in Table III.

TABLE III

PERCENTAGE OF SURVIVAL OF SHOOTS PLANTED IN DRY SOILS

Kind of sett	Dates of transplantation 1-9-1951	22-8-1952	4-10-1953	Average
Double Shoot	96.60	83.90	54.50	78.33
Single Shoot	75.50	69.10	22.91	55.87
Double Seedling	—	85.00	64.58	74.79
Single Seedling	93.30	78.70	19.14	63.73
			Average	68.18

The percentage of survival of Double Shoot and Seedling setts was higher than that in Single Shoot and Seedling setts. The higher percentage of mortality in Single Shoot and Seedling setts appears to be due to the insufficiency of plant food and water in the small portions of internodes attached to them. The finding of Dillewijn that "the larger the cutting attached to a bud, the better the germination" appears to be applicable even to the survival of Shoots and Seedling setts. It was also observed that higher temperature in the month of October was detrimental to the survival of shoots and seedlings.

During the three seasons from 1951-52 to 1953-54, the transplanting of Shoots and Seedling setts was done in dry soil. Since higher percentage of mortality was observed under these conditions, transplanting was done in wet soil in the season 1954-55. The survival percentages are given in Table IV.

TABLE IV

SURVIVAL PERCENTAGE IN SHOOT AND SEEDLING SETTS PLANTED IN WET SOIL

DATE OF TRANSPLANATION : 4-9-1954.

Kind of sett		Survival percentage
Double Shoot		96.5
Single Shoot		95.8
Double Seedling		92.7
Single Seedling		94.1
	Average	94.8

It is seen from the results given in Tables III and IV that the wet condition of the soil before transplantation is a pre-requisite ensuring an appreciably high percentage of survival of Shoot and Seedling setts.

PLANT POPULATION

Tables V and VI give the figures of plant population per acre recorded on different dates of observation.

TABLE V

POPULATION OF PLANTS PER ACRE IN 1952-53 SEASON

Kind of planting	Date of planting or transplanting	Dates of observation			
		6-10-52	16-1-53	20-4-53	24-7-53
Triple Bud (Early)	10-7-1952	82866	89066	82066	52266
Triple Bud (Late)	22-8-1952	14488	114800	109666	48600
Double Shoot	22-8-1952	26066	119200	98800	53266
Single Shoot	22-8-1952	21333	110800	93400	47800
Double Seedling	22-8-1952	29466	127466	107733	50866
Single Seedling	22-8-1952	23733	117600	82600	48866

TABLE VI

POPULATION OF PLANTS PER ACRE IN 1953-54 SEASON

Kind of planting	Date of planting or transplanting	Dates of observation 19-11-53	4-7-54
Triple Bud (Early)	12-8-53	56266	54000
Triple Bud (Late)	4-10-53	14866	53200
Double Shoot	4-10-53	12075	60400
Single Shoot	4-10-53	9363	36708
Double Seedling	4-10-53	18444	49600
Single Seedling	4-10-53	8475	35328

From Tables V and VI, it can be seen that Triple Bud Setts (Early) got an early start which gave rise to early tillering. There was however very little difference in the final number of tillers in the different kinds of setts in the season 1952-53. The plant population in Single Shoot and Seedling setts was very much low in the season 1953-54 which was due to low percentage of survival in these kinds of setts.

GROWTH

Growth measurements were taken periodically and the same are given in Tables VII.

TABLE VII

AVERAGE HEIGHT OF PLANTS IN INCHES IN 1952-53

Kind of planting	Dates of observation 8-12-1952	30-1-1953	9-4-1953	11-8-1953
Triple Bud (Early)	22.60	34.70	47.90	89.10
Triple Bud (Late)	9.16	15.10	26.60	71.20
Double Shoot	8.88	14.70	26.90	68.80
Single Shoot	9.70	16.80	31.70	75.40
Double Seedling	8.90	14.20	26.60	66.40
Single Seedling	9.20	15.00	28.30	72.50

From the above Table, it is seen that the growth progressed rapidly in Triple Bud setts (Early). The growth in other kinds of setts was almost equal.

HARVEST DATA

Detailed harvest data were collected and the same are presented in Table VIII.

TABLE VIII

HARVEST DATA IN DIFFERENT TREATMENTS -AVERAGE OF TWO SEASONS 1952-53 AND 1953-54

Details	Triple Bud (Early)	Triple Bud (Late)	Double Shoot	Single Shoot	Double Seedling	Single Seedling
No. per acre						
Normal canes	46426	40555	38302	35080	37415	37579
Water Shoots	10456	3564	4576	3717	3567	4422
Total Millabe canes	57282	44119	42878	38797	40982	42001
Dead Canes	12735	Nil	1295	1896	1358	572
Av. Height in inches						
Normal canes	87.32	88.85	94.11	92.40	91.80	94.40
Water Shoots	41.10	50.70	52.20	40.90	46.40	38.00
Av. Girth in inches						
Normal canes	2.50	2.59	2.37	2.40	2.53	2.75
Water Shoots	3.36	3.00	2.76	3.08	3.16	3.30
Av. Weight in lbs.						
Normal canes	2.42	3.31	2.49	2.30	2.50	1.84
Water Shoots	1.79	1.85	1.70	1.14	1.32	1.83
Millable canes	2.12	2.45	2.23	2.16	2.00	1.49

The number of normal canes, water shoots and also millable canes in Triple Bud setts (Early) was higher than that in all other kinds of setts although there was a higher percentage of dead canes owing to the heavy lodging and rat attack during the season 1953-54. The height of normal canes in Shoot and Seedling setts was higher than that in Triple Bud setts, both Early and Late. The weight of millable canes in Single Seedling was abnormally low as compared to other kinds of setts.

YIELD DATA

The data for season 1951-52 are given in Table IX separately, as there were only five treatments during this season.

TABLE IX

YIELD OF CANE, PERCENTAGE OF AVAILABLE SUGAR AND SUGAR PER ACRE IN 1951-52

Kind of sett	Yield of cane per acre Tons	Available Sugar Tons	Sugar Per acre Tons
Triple Bud (Early)	79.84	11.48	9.16
Triple Bud (Late)	64.44	11.69	7.56
Double Shoot	71.52	11.11	7.95
Single Shoot	68.80	11.93	8.21
Single Seedling	66.90	11.34	7.59
Critical difference at 5% level	6.68		

Triple Bud setts (Early) were found to be distinctly superior to all other kinds of setts both in respect of yield and sugar per acre. Double Shoot and Single Shoot setts gave more or less equal amount of sugar per acre. Triple Bud (Late) and Single Seedling setts were found to be inferior to other treatments.

The results for 1952-53 season are given in Table X.

TABLE X

YIELD OF CANE, PERCENTAGE OF AVAILABLE SUGAR AND SUGAR PER ACRE IN 1952-53

Kind of sett	Yield of cane per acre Tons	Available Sugar Tons	Sugar per acre Tons
Triple Bud (Early)	45.68	10.87	4.96
Triple Bud (Late)	39.78	11.04	4.39
Double Shoot	37.01	12.68	4.69
Single Shoot	35.74	12.39	4.07
Double Seedling	38.60	12.33	4.76
Single Seedling	37.29	12.24	4.57
Critical Difference	3.77		

The results in Table X confirm the finding of 1951-52 season as regards the superiority of Triple Bud setts (Early) in respect of yield and sugar per acre. The yield of cane and sugar in Double Shoot, Double Seedling and Single Seedling setts was almost equal. Triple Bud (Late) although second in yield was lower as regards sugar per acre. The yield of cane and sugar per acre in Single Shoot setts was the least.

The percentage of available sugar in Shoot and Seedling setts was distinctly higher than that in Triple Bud setts both Early and Late.

The results for the season 1953-54 are given in Table XI.

TABLE XI

YIELD OF CANE, PERCENTAGE OF AVAILABLE SUGAR AND SUGAR PER ACRE IN 1953-54

Kind of sett	Yield of cane per acre Tons	Available sugar Tons	Sugar per acre Tons
Triple Bud (Early)	45.60	11.85	5.86
Triple Bud (Late)	47.40	14.24	6.75
Double Shoot	45.22	14.83	6.72
Single Shoot	39.71	14.42	5.72
Double Seedling	39.52	13.75	5.44
Single Seedling	32.21	14.26	4.59
Critical Difference at 5% level	5.75		

The yield of cane in Triple Bud setts (Early) was reduced by about 28% due to severe rat attack. Other treatments remained practically unaffected by this pest. The loss of cane due to rat attack in early planted crops was found to be comparatively very high during this season (4). The yield of cane in Triple Bud (Early) and (Late) and Double Shoot was superior to other kinds of setts. The sugar per acre in Triple Bud (Late) and Double Shoot setts was almost equal. Out of the remaining treatments, Single Seedling yielded the least in respect of cane as well as sugar per acre.

TABLE XII

ANALYSIS OF VARIANCE

Due to	D.F.	S.S.	M.S.S.	F
Blocks	10	4.96	—	
Treatments	5	5.45	1.09	
Seasons	1	0.43	0.43	
Tr. x Seasons	5	1.96	0.39	
Error	50	5.55	0.11	
Sig. at 5% level				3.5

The Table of Analysis of Variance of the yields of two seasons combined together show that Treatment × Season interaction is significant, compared to the error-mean sum of squares. The "F" value due to treatment does not turn out to be significant, compared to the Treatment × Season mean sum of squares.

The average results for the seasons 1952-53 and 1953-54 are given in Table XIII.

TABLE XIII

YIELD OF CANE, PERCENTAGE OF AVAILABLE SUGAR AND SUGAR PER ACRE
(Average of 2 Seasons)

Kind of sett	Yield of cane per acre Tons	Available sugar Tons	Sugar per acre Tons
Triple Bud (Early)	45.64	11.86	5.41
Triple Bud (Late)	43.59	12.64	5.57
Double Shoot	41.11	13.75	5.70
Single Shoot	37.72	13.40	4.89
Double Seedling	39.06	13.04	5.10
Single Seedling	34.75	13.25	4.58
Critical Difference at 5% level	6.38		

Double Shoot setts gave more sugar per acre than all other treatments.
Triple Bud—both Early and Late—were almost equal as regards sugar per acre.
Double Seedling, Single Shoot and Single Seedling setts were found to be inferior to other treatments both in yield and sugar per acre.
The percentage of available sugar in Shoot and Seedling setts was appreciably higher than that in Triple Bud setts—both Early and Late.

DISCUSSION

Triple Bud setts (Early) get early start and better conditions for growth and tillering. This is reflected in the higher yield of cane in the first two seasons. In the third season, the results were vitiated due to severe rat attack. The higher yield of this kind of planting is mainly due to the more number of millable canes. The percentage of available sugar is, however, affected owing to the composition of larger number of water shoots present in this kind of planting.

Triple Bud setts (Late) give a slightly higher yield than Double Shoot setts, but are lower in sugar content. The sugar yield per acre from these two kinds of plantings is almost equal.

Double Shoot setts yield canes which are richer in sugar content than all other kinds of setts. This kind of planting seems to be advantageous over all other kinds of planting, except Triple Bud setts (Early).

Double Seedling setts are superior to Single Shoot and Single Seedling setts, as regards yield and sugar per acre, mainly because of higher percentage of survival in this kind of setts.

Transplantation gives a set-back to Seedling setts in the beginning, probably because of the injury to the roots present in these kinds of setts. As the sett-roots are not present in Shoot setts, the extent of set-back in these kinds of setts is less as compared to Seedling setts.

SUMMARY AND CONCLUSIONS

A comparative study of planting Shoot and Seedling setts—both Double and Single—with Triple Bud setts—both Early and Late—was carried out at Ugarkhurd, Bombay State, during the monsoon seasons from 1953 to 1954. The conclusions that can be drawn from this study are —

1. Triple Bud setts (Early) are definitely superior to all other kinds of plantings.
2. If early planting of Triple Bud setts is not possible due to floods or any other reasons, the planting of Double Shoot setts seems to be preferable to all other kinds of setts planted at the same time.
3. Double Seedling, Single Shoot and Single Seedling setts are inferior to Triple Bud setts—both Early and Late—and Double Shoot setts.
4. The percentage of available sugar in cane in the planting of Shoot and Seedling setts in general and Double Shoot setts in particular, is appreciably higher than that in Triple Bud Setts.
5. From the point of view of survival of Shoot and Seedling setts, transplanting in wet soil is better than that in dry soil.

ACKNOWLEDGMENT

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3. Dr. H. R. Arakeri, Ph. D., Sugarcane Specialist, and Shri A.V.R. Rao, Statistician, Sugarcane Research Station, Padegaon, for their help and guidance in presenting this paper.

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DISCUSSION

Mr. Bab Lal remarked that under normal planting there was a high rate of mortality of tillers which had already taken up the major quantity of the nutrients resulting in a loss to the crop but with a space of one foot for all tillers in a row under single eye bud planting, higher yield and sugar content was ensured along with a saving of 66 percent in seed. Mr. Manjaiah supported this view and said that vertical planting and transplanting gave longer period of growth to the canes resulting in higher yield and sugar, besides effecting a saving in seed. He opined that it could be profitably tried in U.P. and Bihar where the growth period of cane was short. Dr. Arakeri remarked that his method was being followed in Kolhapur factory for the last 15 years where the highest recoveries in the country were obtained. Mr. King observed that results obtained with planting of setts having different number of buds were largely dependent on edaphic and climatic conditions and as such differed from country to country. In Queensland the ultimate stand of cane was uniform, whatever might be the number of eye buds and seed pieces planted. Dr. Abbott said that in Louisiana there was a direct correlation between size of seed piece and yield, 5 eye bud setts giving the highest yield which also was incidentally a practicable proposition from the point of view of mechanical cultivation. In his opinion although a single-eye piece gave higher germination and proved economical, the plants were not vigorous. Dr. Venkatraman said that the question of 2, 3 and 5 budded setts had been examined at Coimbatore a quarter of a century ago and the amount of tissue that should go with the bud to give a healthy seedling had also been assessed. He wanted to know the length of internodal tissue used with a single-eye piece in this case. Mr. Girdhari Lal thought that *rayungans*, though increasing yield by 15 percent, were very delicate in nature for handling and posed practical difficulties along with high cost. He also said that their sugar content was lower by 5 to 8 percent. Mr. C.N. Agarwal wanted to know whether *rayungan* was at all responsible for the high recoveries obtained in Kolhapur.

Mr. Harbans Singh presented the following paper.

Paper

SEASONAL PLANTING OF SUGARCANE IN PUNJAB (INDIA)

Harbans Singh And Hardial Singh

Sugarcane Research Station, Jullundur, India

INTRODUCTION

Punjab, situated between 28°—33° North and 74°—77° East, occupies the most northernly position amongst the major cane growing States of the Indian Union. It experiences extreme of climates, in winter the mercury falling 3°F to 4°F below freezing point and in summer the maximum temperature rising to over 116°F. In spite of such climatic disabilities, sugarcane, essentially a crop of the tropics, occupies a very important place in the State and in the matter of cane acreage, Punjab occupies second position and contributes over 8 percent of the total cane area in the Union. The Punjab farmer has been accustomed to grow cane from times immemorial and is destined to grow it for centuries to come.

Short growing season is considered one of the factors responsible for low yields in Punjab, as also in Northern India. It was, therefore, planned to see if autumn and winter plantings could improve yield and quality of cane, compared to normal planting season in the Punjab. Louisiana, having almost similar climate as Punjab, tried summer and fall planting to improve its cane crop.

MATERIAL AND METHOD

The trials were conducted at the Sugarcane Research Stations at Jullundur and Gurdaspur, representing the central and sub-montane cane growing tracts respectively. For autumn sowing, cane was planted in September-October, for winter planting in December and for early summer planting in April. These seasonal plantings were compared with normal spring planting done in February-March. Different crop rotations were followed for different seasonal plantings. Summer fodder (great millet), Indian clover, rape, and wheat crops preceded cane while gram at Jullundur and lentil at Gurdaspur were sown as inter-crops in the case of autumn planting.

The lay-out was a simple randomized block design with four replications, net plot size being 1/40th acre. The variety sown in all these trials was Co. 312.

The experiment had a straight run of four seasons (1950-52, 1951-53, 1952-54 and 1953-55). The treatments were —

A. Autumn planting	T_1	September planting after great millet (*Andropogon sorghum*).
	T_2	September planting plus gram (*Cicer ariltinum*) as inter crop.
B. Winter planting	T_3	December planting after summer fodder (*Andropogon sorghum*).
	T_4	December planting after rape crop (*Brassica napus*).
C. Spring planting	T_5	March planting after summer fodder (*Andropogon sorghum*).
	T_6	March planting after Indian clover (*Melilotus perviflora*).
D. Early summer planting	T_7	April planting after summer fodder (*Andropogon sorghum*).
	T_8	April planting after wheat (*Triticum sativum*).

EXPERIMENTAL DATA

The data regarding bionomics, yield, quality and economics etc., for four complete cycles have been dealt with separately for each season, as also in the combined form to work out the effect of seasons and rotations etc.

A. GERMINATION

Germination phase in the case of autumn and spring plantings, completed in about six weeks, the normal time taken under Punjab conditions, while in the case of early summer planting, it was completed in four-five weeks. Buds in the case of winter planting remained dormant for about six to eight weeks and took another four to five weeks in spring to complete germination. Germination data alongwith the minimum soil temperature are given in the Tables I (a) and I (b).

TABLE I (a)

GERMINATION PERCENTAGE DURING DIFFERENT YEARS

Treatments	Rotation	1951-52	1952-53	1953-54	Average for Treatment	Average for Planting season
T_1—Autumn planting after summer fodder	R_1	*30.3	30.9	35.2	32.1	33.3
T_2—Autumn planting cane inter-cropped with gram	R_2	*34.1	35.2	34.3	34.5	
T_3—Winter planting after summer fodder	R_1	43.4	38.4	34.3	38.7	37.5
T_4—Winter planting after rape	R_2	40.6	34.3	33.9	36.3	
T_5—Spring planting after summer fodder	R_1	47.4	40.5	38.7	42.2	41.7
T_6—Spring planting after Indian clover	R_2	42.2	41.6	39.7	41.2	
T_7—Early summer planting after summer fodder	R_1	31.4	37.8	31.0	33.4	32.8
T_8—Early summer planting after wheat	R_2	30.9	35.4	30.0	32.1	

* Planting done in early October.

TABLE I (b)

RANGE OF SOIL TEMPERATURE (°F) AT 15 cm. DEPTH

Month	1951-52	1952-53	1953-54	Widest range
September	91.2—96.4	89.4—97.1	87.8—95.0	87.8—97.1
October	86.9—90.4	83.2—86.0	82.6—87.4	82.6—90.4
November	72.9—75.8	69.4—72.8	67.8—72.7	67.8—75.8
December	59.2—64.0	54.8—59.5	57.3—64.3	54.8—64.3
January	58.0—61.8	50.1—56.8	49.7—57.6	49.7—61.8
February	61.9—66.5	55.9—63.2	57.0—64.0	55.9—66.5
March	68.5—74.4	72.6—76.4	62.3—74.2	62.3—76.4
April	83.4—88.2	75.2—82.9	77.5—92.4	75.2—92.4
May	90.2—96.0	92.6—96.7	88.4—102.5	88.4—102.5

Buds germinating at different periods in the case of different seasonal plantings did not show any marked difference in the total strength of germination except that spring planting, resulted in higher germination than others. Planting cane after fallow is suggestive of a beneficial effect on germination.

The autumn planted (September) crop completed its germination by about the beginning of November when the average minimum soil temperature ranged from 82.6°F to 89.4° F and the percent germination from 30.3 to 35.2. Spring planted (March) crop completed this phase by end of April with the minimum soil temperature varying from 62.3°F to 83.4°F and germination from 38.7 to 47.4 percent. Early summer (April) crop completed its germination varying from 30.9 to 37.8 percent by the third week of May, with the minimum soil temperature ranging from 75.2°F to 92.6°F. In the case of winter (December) planted crop, the buds did not germinate during December-January when the minimum soil temperature varied from 54.8°F to 59.30°F in December and 49.7°F to 58.0°F in January. Germination varying from 33.9 to 43.4 percent in this case was also completed in February-March when the minimum soil temperature rose and varied from 55.9°F to 72.6° F. The minimum soil temperature of 62.3°F to 83.4° F was found conducive to good germination.

B. TILLERING

In the case of winter, spring and early summer plantings, the tillering phase started after the completion of germination, whereas in the case of autumn planting there had been practically no tiller production during December-January due to low air temperature (30.7°F to 44.9° F) and soil temperature (49.7°F to 59.3°F). Tiller production in autumn, winter and spring plantings reached its maximum by June after which decline in their number sets in due to mortality. In the case of summer planting, where tiller production started in June, there was a progressive increase till July-August but a fall thereafter.

On statistical working, the combined figures for four cycles showed the following results :—

Seasons of planting

					C.D. at 5%
June	Autumn	Winter	Spring	Early Summer	
	(6.9)	(6.8)	(5.8)	(3.9)	6.73
Sept.	Autumn	Spring	Winter	Early Summer	
	(5.1)	(4.6)	(4.6)	(4.2)	N.S.
Nov.	Winter	Autumn	Spring	Early Summer	
	(3.9)	(3.8)	(3.8)	(3.6)	N.S.

Rotations

June	R_1	R_2	
	(6.3)	(5.4)	0.73
Sept.	R_1	R_2	
	(4.9)	(4.5)	N.S.
Nov.	R_1	R_2	
	(3.91)	(3.6)	0.21

TABLE II

SHOWING THE NUMBER OF TILLERS PER CLUMP

Year	Month	Planting season							
		Autumn		Winter		Spring		Early Summer	
		T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8
1950—52	June	8.6	2.5	5.8	5.6	6.0	4.9	3.9	2.6
	September	3.6	4.0	4.5	3.3	4.6	3.7	4.0	3.8
	November	3.5	3.8	4.0	3.2	4.5	3.6	4.0	3.5
1951—53	June	7.0	6.9	8.3	7.9	5.4	5.9	3.8	3.9
	September	4.5	3.8	5.3	3.7	4.2	4.0	4.5	5.2
	November	4.1	3.5	4.9	3.5	3.9	3.7	4.2	4.0
1952—54	June	8.3	7.5	7.1	5.8	5.8	5.2	4.5	3.8
	September	6.2	6.3	5.1	4.2	4.9	3.7	4.2	4.0
	November	3.2	3.2	3.2	3.2	3.0	2.4	2.8	2.4
1953—55	June	7.5	7.2	7.9	6.1	6.8	6.1	4.7	4.3
	September	6.5	6.2	5.4	5.6	6.3	6.0	4.2	3.9
	November	4.6	4.8	4.9	4.4	4.3	4.8	3.7	3.9
Average for 4 years	June	7.9	6.0	7.2	6.4	6.0	6.5	4.2	3.7
	September	5.2	5.1	5.1	4.2	5.0	4.0	4.2	4.2
	November	3.9	3.8	4.2	3.6	3.9	3.6	3.7	3.5

N.B. See details of treatments under METHOD AND MATERIAL

The maximum tiller production by November showed a percent mortality of 44.6 in autumn, 42.6 in winter, 34.8 in spring and 10.1 percent in early summer planted crop. The higher mortality in the case of first three plantings narrowed down the original differences to a non-significant level. Crop planted after fallow produced significantly higher number of tillers (cane formed plus uncane-formed shoots) than the other rotations, especially where intercropping was followed.

C. GROWTH

Cane stalks were selected at random in all replications, ten in each plot, for measurement of linear growth. The measurement data are given in Table III.

The statistical analysis of the combined data for the four crop cycles revealed the following conclusions :

Season of planting

June	Autumn	Winter	Spring	Early Summer	C.D. at 5%
	(16.2)	(16.0)	(14.1)	(8.8)	2.50
Sept.	Winter	Spring	Autumn	Early Summer	
	(70.3)	(68.7)	(68.2)	(62.0)	5.14
Nov.	Winter	Autumn	Spring	Early Summer	
	(75.9)	(75.4)	(75.1)	(68.9)	4.37

Rotations

June	R_1	R_2	
	(14.1)	(13.4)	N.S.
Sept.	R_1	R_2	
	(69.7)	(64.9)	3.44
Nov.	R_1	R_2	
	(75.8)	(71.8)	3.12

The growth of the crop planted late in the season (early summer) remained stunted and slow even after the monsoon and differences in linear growth were significantly in favour of winter, spring and autumn planting. Crop sown after fallow made significantly better growth as compared to that sown under other rotations.

D. CANE YIELD

Crop from the different seasonal plantings during the conduct of this experiment was harvested in January-February. Thus, the crop in the case of autumn winter, spring and early summer plantings remained on the soil for about 16-17, 13-14, 10-11, 9-10, months respectively. The yield data for the two stations, Jullundur and Gurdaspur, where this experiment was conducted for the different seasons, are given in Table IV.

TABLE III

HEIGHT OF STALK IN INCHES

Year	Month	Planting season							
		Autumn		Winter		Spring		Early summer	
		T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8
1950-52	June	10.0	5.6	13.0	12.5	9.1	9.5	7.0	6.8
	September	57.3	51.3	60.4	57.5	58.4	61.5	56.6	55.4
	November	64.1	52.8	66.2	61.6	62.4	65.2	62.9	59.6
1951-53	June	22.8	20.8	18.3	17.3	13.5	14.3	9.9	8.5
	September	79.4	70.2	75.8	67.9	63.6	62.7	66.2	60.7
	November	83.5	73.7	79.7	70.8	67.8	66.5	69.3	66.3
1952-54	June	14.2	15.5	14.2	14.1	15.1	15.1	10.6	10.1
	September	82.4	59.5	80.3	72.4	78.6	77.9	68.1	60.0
	November	82.7	72.2	80.5	72.7	79.8	82.6	70.2	63.0
1953-55	June	21.1	19.8	20.0	18.5	18.0	17.9	8.8	8.9
	September	71.2	74.6	74.6	73.8	74.5	72.2	67.0	62.0
	November	86.4	87.9	88.9	86.9	88.4	88.4	80.7	79.4
Average for four years	June	17.1	14.9	16.4	15.9	13.7	14.2	9.1	8.6
	September	72.6	63.9	72.8	67.9	68.8	68.6	64.5	59.5
	November	79.0	71.7	78.8	73.0	74.6	75.7	70.8	67.1

N.B. See details of treatments under METHOD AND MATERIAL.

TABLE IV

Treatment	Rotation	Yield of cane per acre in maunds			
		1950-52	1951-53	1952-54	1953-55
	JULLUNDUR				
T_1—Autumn planting	R_1-W-Kh-C	606.0	752.0	1006.8	845.2
T_2—Autumn planting	R_2-W-Kh-G*+C	460.0	678.0	802.8	894.4
T_3—Winter planting	R_1-W-Kh-C	671.3	720.4	958.3	835.2
T_4—Winter planting	R_2-W-Kh-Sn-C	632.7	534.4	842.2	766.8
T_5—Spring planting	R_1-W-Kh-C	620.1	536.0	904.2	852.0
T_6—Spring planting	R_2-W-Kh-S-C	643.5	512.8	842.2	832.4
T_7—Early summer planting	R_1-W-Kh-C	589.5	465.4	682.6	598.0
T_8—Early summer planting	R_2-W-Kh-W-C	515.0	388.8	521.2	523.2
	GURDASPUR				
T_1—Autumn planting	R_1-W-Kh-C	—	340.2	664.3	928.4
T_2—Autumn planting	R_2-W-Kh-L*+C	—	341.6	564.5	826.9
T_3—Spring planting	R_1-W-F-C	—	360.0	505.8	952.9
T_4—Spring planting	W-S-C	—	319.8	—	—
T_5—Summer planting	R_1-W-F-C	—	225.2	435.0	810.3
T_6—Early summer planting	R_2-W-F-W-C	—	162.4	338.0	682.5
T_7—Early summer planting	R_2-W-F-L-C	—	—	387.3	765.8

*The inter-crop with cane at Jullundur was gram and at Gurdaspur lentil.

Symbols

W — Wheat
Kh — Summer fodder (great millet)
C — Sugarcane
G — Gram
Sn — Rape
S — Indian clover
F — Fallow
L — Lentil
R_1 — Rotation where cane was planted after fallow
R_2 — Rotation where cane followed a catch crop or was sown with an inter crop

N.B. (*i*) Experiment at Gurdaspur was started in 1951.
(*ii*) Winter planting being not possible at Gurdaspur, the treatments were changed from 1952-54 as shown in Table above.
(*iii*) One maund=82.26 lbs.

CONCLUSIONS

JULLUNDUR 1950-52

Treatment	T_3	T_6	T_4	T_5	T_1	T_7	T_8	T_3	C.D. at 5%
	671.3	643.5	632.7	620.1	606.0	589.5	515.0	460.0	91.40
Planting Time	Winter	Spring	Early Summer	Autumn					
	652.0	631.8	552.3	533.0					74.01
Rotations	Non significant								60.62

JULLUNDUR 1951-53

Treatment	T_1	T_3	T_2	T_5	T_4	T_6	T_7	T_8	
	752.0	720.4	678.0	536.0	534.4	512 8	465.4	388.8	82.70
Planting Time	Autumn	Winter	Spring	Early Summer					
	715.0	627.4	524.4	427.1					56.60
Rotation	R_1	R_2							
	618·5	528.5							41.43

GURDASPUR 1951-53

Treatment	T_3	T_2	T_1	T_4	T_5	T_6	
	360.0	341.6	340.2	319,8	225.2	162.4	20.55
Planting Time	Autumn	Spring	Early Summer				
	340.9	339.9	193.8				14.51
Rotation	R_1	R_2					
	308.5	274.6					18.77

JULLUNDUR 1952-54

Treatment	T_1	T_3	T_5	T_4	T_6	T_2	T_7	T_8	
	1006.8	958.8	904.2	842.2	842.2	802.8	682.6	521.2	37.40
Planting Time	Autumn	Winter	Spring	Early Summer					
	904.8	900.5	873.2	601.9					54.07
Rotation	R_1	R_2							
	888.1	652.1							38.30

GURDASPUR 1952-54

Treatment	T_1	T_3	T_3	T_4	T_5	T_6	
	664·3	564.5	505.8	435.0	387.3	338.0	77.62
Planting Time	Autumn	Spring	Early Summer				
	614.4	505.8	386.8				61.36
Rotation	R_1	R_2					
	535.0	429.9					44.99

JULLUNDUR 1953-55

Treatment	T_2	T_5	T_1	T_3	T_6	T_4	T_7	T_8	
	894.4	852.0	845.2	835.2	832.4	766·8	598.0	523.2	107.95

Planting Time	Autumn	Spring	Winter	Early Summer	
	869·8	842.2	801.0	560.6	78.30
Rotation	Non Significant				

GURDASPUR 1953-55

Treatment	T_3	T_1	T_2	T_4	T_5	T_6	
	952.9	928.4	826.9	810.3	765.8	682.5	111.40
Planting Time	Spring	Autumn	Early Summer				
	952.9	877·6	752.9				103.1
Rotation	R_1		R_2				
	897.2		758.4				64.3

Barring 1950-52, when autumn planted crop gave comparatively low yield, the yields of the early summer planted crop were significantly less than those from other plantings at both the stations. The yield differences between autumn, winter and spring plantings were non-significant at Jullundur during 1952-54 and 1953-55 and at Gurdaspur in 1953-55. Such differences in 1951-53 at Jullundur and 1952-54 at Gurdaspur showed significant differences and were in favour of autumn and winter plantings.

The low yield of autumn planting in 1950-52 was mainly due to the poor yield where gram was sown as intercrop in this seasonal planting. Cane crop in this case was of low vigour and pale yellow colour from the very start and produced the least number of tillers compared to other treatments. Gram sown as intercrop being of a bushy type, greatly interfered with the normal development of cane plants, resulting in low yield under this treatment. The low temperature (28.7°F) in December, 1950, and the continuous frosts during 23 nights in that year also affected adversely the plants in the case of autumn planting. In 1951-53, the previous local variety of gram with spreading habit was replaced by another comparatively less bushy variety, locally called as *Kabli* gram. This new variety yielded 8.65 maunds per acre against the yield of 16.8 maunds of the previous variety in 1950-52 planting cycle. The winters during 1951-53 to 1953-55 were mild, the range of minimum temperature being 35.8°F to 40.0°F and consequently the autumn planted crop was not adversely affected due to low temperature. BHC 5% dust used at sowing time in the case of autumn planting checked white ant attack. In 1950-52, however, stand of the crop in this treatment suffered due to the appearance of this pest as BHC could not be applied.

In case of all plantings the yields were in favour of rotation R_1, i.e., planting after fallow, as compared to other rotations where cane was sown after a catch crop or with intercrop.

CONSOLIDATED RESULTS FOR FOUR CROPS 1950-52 TO 1953-55

The yield results for the different years have been consolidated and the average figures for planting seasons, rotations, etc., are given in Tables V (a) and V (b).

TABLE V (a)

SHOWING AVERAGE YIELDS FOR FOUR CYCLES (1950-52 TO 1953-55)

Particulars	Rotation*	Average yield for four years (mds. per acre)	
		Rotation	Planting season
JULLUNDUR			
T_1—Autumn planting	W-Kh-C (R_1)	802.5	755.7
T_2—Autumn planting	W-Kh-G+C(R_2)	708.8	
T_3—Winter planting	W-Kh-C (R_1)	796.4	745.2
T_4—Winter planting	W-Kh-Sn-C (R_2)	694.0	
T_5—Spring planting	W-Kh-C (R_1)	728.1	717.9
T_6—Spring planting	W-Kh-S-C (R_2)	707.7	
T_7—Early summer planting	W-Kh-C (R_1)	583.9	535.5
T_8—Early summer planting	W-Kh-W-C (R_2)	487.1	
Over all average for	$R_1$727.6 and R_2 649.4		
GURDASPUR			
T_1—Autumn planting	W-Kh-C (R_1)	796.4	746.1
T_2—Autumn planting	W-Kh-L+C (R_2)	695.7	
T_3—Spring planting	W-F-C (R_1)	729.4	729.4
T_4—Early summer planting	W-F-C (R_1)	622.7	569.8
T_5—Early summer planting	W-F-W-C (R_2)	510.3	
T_6—Early summer planting	W-F-L-C (R_2)	576.5	
Over all average for	R_1 580.2 and R_2 487.6		

*For details of treatment see under Material and Method.

TABLE V (b)

INTERACTION YEAR AND PLANTING SEASON, JULLUNDUR

Planting season	Years			
	1950-52	1951-53	1952-54	1953-55
Autumn	633.0	715.0	904.8	900.5
Winter	652.0	560.6	869.8	801.0
Spring	631.8	524.4	873.2	842.2
Early summer	522.2	426.1	601.9	560.6

The above data, when put to combined analysis to see the overall effect of the different factors under study, gave the following conclusions at 5% level of significance :—

JULLUNDUR

Years	1952-54	1953-55	1950-52	1951-53	C.D. at 5%
	820.1	768.4	592.3	573.5	39.94
Planting season	Autumn	Winter	Spring	Early Summer	
	755.7	745.2	717.9	535.5	39.94
Rotation	R_1		R_2		
	727·6		649.4		28.24
Interaction	Significant				57.00

GURDASPUR

Years	1953-55	1952-54	1951-53
	827.8	482.5	291.5
Planting season	Autumn	Spring	Early Summer
	746.1	729.4	569.8
Rotations	R_1	R_2	
	580.2	487.6	

Years—In 1950-52, the autumn planted crop at Jullundur suffered in its yield due to the interference of a bushy gram variety which formed a sort of canopy over the young plants as also due to the ill effects of severe frosts when the minimum temperature fell down to 28.7°F. This affected the overall yield of the different plantings in 1950-52 cycle. The low yields in 1951-53 were the result of high incidence of Top Borer (*Scirpophaga nivella* F.) which affected adversely the crop under almost all the plantings. The winter and summer were also unfavourable at Gurdaspur, resulting in low yields of different seasonal plantings. The yields were significantly higher in 1952-54 and 1953-55.

Rotations— Barring Indian clover (*Melilotus parviflora*) where the catch crop did not affect adversely the yield of cane in the case of spring planting the catch crop or the intercropping with cane showed depressing effect on cane yield in the case of almost all plantings. The rotation where sugarcane was sown after fallow invariably gave higher yields in the case of different seasonal plantings.

Planting seasons—Although the yield of autumn planting was low at Jullundur in 1950-52 for reasons already explained, the overall results showed non-significant differences amongst autumn, winter and spring plantings. These various seasonal plantings gave significantly higher yield than early summer planting.

E. JUICE QUALITY

Crop from the different treatments was analysed during the following winter in November and January-February to compare the progress of ripening in the case of different seasonal plantings. The data are as under :—

TABLE VI

Planting season	R_1				R_2			
	November		Jan.-Feb.		November		Jan-Feb.	
	Suc.%	Pty.	Suc.%	Pty.	Suc.%	Pty.	Suc.%	Pty.
1950-52								
Autumn	10.1	66.7	14.4	79.4	11.7	73.4	16.2	86.5
Winter	10.7	69.5	15.3	83.9	—	—	16.0	85.7
Spring	9.2	61.8	15.5	82.9	9.4	65.7	16.1	86.6
Early Summer	11.4	74.0	15.8	85.2	11.4	73.5	16.1	85.4
1951-53								
Autumn	10.7	73.4	15.0	89.5	11.6	72.9	16.2	90.8
Winter	11.6	74.8	15.8	90.5	11.9	77.3	15.7	91.4
Spring	11.0	73.2	15.9	88.2	11.8	75.9	15.8	90.2
Early Summer	10.8	71.9	15.5	89.0	11.6	74.5	15.4	89.3
1952-54								
Autumn	12.8	78.0	17.3	91.1	13.0	77.8	18.3	92.0
Winter	12.5	76.7	17.3	90.1	13.0	77.4	16.3	89.6
Spring	11.9	74.4	16.0	87.0	12.5	75.3	16.7	88.4
Early Summer	12.4	75.6	17.3	91.1	13.6	80.4	17.6	90.2
1953-55								
Autumn	10.7	68.0	15.0	81.7	10.8	67.5	15.3	81.6
Winter	10.4	67.4	15.8	82.9	10.2	65.4	14.6	82.9
Spring	9.7	63.2	15.2	77.9	8.9	61.1	14.4	80.6
Early Summer	9.4	62.1	14.6	80.9	9.4	62.1	14.8	79.1

N.B.—R_1 denotes treatments in which cane has been planted after fallow.
R_2 denotes treatments in which cane has been planted after a catch crop or with intercropping.

The juice analysis results on the whole did not show any appreciable difference in the case of different seasonal plantings, though they were suggestive in favour of autumn planting. In 1952-54 and 1953-55, the November results were in favour of autumn planting. The results further indicate that irrespective of the season of planting cane, juice quality is closely associated with the final tonnage of the crop.

In the case of autumn, winter and spring plantings, the final tonnage was almost alike and likewise the differences in juice quality in the case of these plantings were rather very narrow. However, the autumn planting with gram as intercropping showed slightly higher sucrose and the yield in this case was significantly low. The slightly better quality juice in the case of early summer

(April) planting in two out of the four years the trial was in progress, was due to the poor condition of the crop resulting in low yield than the effect of time of planting.

F. ECONOMICS

Records for the cost of cultivation of different crops sown in the different rotations were maintained to work out the income from different seasonal plantings. The average income for the last three cycles for which records were maintained is as under :—

TABLE VII (a)

JULLUNDUR

Treatment	Income	Cost of Cultivation	Net profit for	
			Treatment	Seasonal planting
	Rs.	Rs.	Rs.	Rs.
T_1—September planting cane alone	1200.6	575.3	625.3	615.6
T_2—September planting cane plus gram	1095.9 88.9	578.1	606.7	
T_3—December planting cane alone	1159.7	561.6	598.1	529.8
T_4—December planting cane after rape	994.6 97.9	631.1	461.4	
T_5—Spring planting cane alone	1064.9	507.5	557.4	596.3
T_6—Spring planting cane after Indian clover	1015.9 247.8	628.5	635.2	
T_7—Early summer planting cane alone	804.0	525.1	278.9	316.9
T_8—Early summer planting cane after wheat	662.6 311.9	619.6	354.9	

TABLE VII (b)

GURDASPUR

Treatment	Income	Cost of cultivation	Net profit for	
			Treatment	Seasonal planting
	Rs.	Rs.	Rs.	Rs.
T_1—Autumn planting cane alone	987.1	430.0	557.1	542.5
T_2—Autumn planting cane plus lentil	861.4 102.4	436.0	527.8	
T_3—Spring planting cane alone	882.2	458.6	423.6	423.6
T_4—Early summer planting cane alone	761.6	470.6	291.0	338.0
T_5—Early summer planting cane after lentil	708 8 260.7	476 6	392.9	
T_6—Early summer planting cane after wheat	624.1 185.6	479.6	330.1	

Autumn planting gave the highest average net profit followed by spring and winter plantings. The early summer planting gave the lowest net income and it was about 50% of that recorded in the case of the other planting seasons. In regard to the different rotations, it would be seen that while the rotation with catch crop has given the highest net income in spring planting, such a rotation in the case of winter planting has given less income. In the case of autumn planting also, the catch crop has not shown any advantage and the difference in the net income in the case of planting cane after fallow and with catch crop is only nominal. Both from yield and economic considerations, planting of cane in summer is not desirable. Where this has to be resorted to due to special conditions, it would be economical to sow cane after a catch crop (wheat, lentil, etc.) instead of planting it after fallow.

The common practice in the Punjab is to plant cane in spring (February-March) after Indian clover (*Melilotus parviflora*) as a catch crop. While this rotation has given the highest net return and can with advantage be followed by average cane planters, it is not possible in the case of big cultivators to finish their plantings in time under this rotation. In such cases, plantings should be spread over three seasons (autumn, winter and spring).

DISCUSSION

The four years results of different seasonal plantings have given some useful indications on the various developmental activities of the cane plant. Cane planted in autumn took about six weeks to complete its germination and during this period the minimum soil temperature ranged from 82.6° F to 89.4°F and the germination in this case under field conditions was 30.3 to 35.2 percent. In the case of winter planting, almost all the buds remained dormant during the first 6 weeks when the average minimum soil temperature ranged from 49.7° F to 59.3°F. This corroborates the findings of Rykor and Edgerton[1] of Louisiana, who found the minimum temperature of 54.0°F to be essential for growth of buds. Rege and Wagle[2] in India also found the soil temperature below 50.0°F as injurious to germination of buds. The buds started germinating about the middle of February and the germination phase was completed in about 5-6 weeks time when the minimum soil temperature ranged from 55.9°F to 72.6°F. According to Mathur[3], a soil temperature of 66.0°F constituted a critical temperature below which germination was adversely affected. In the case of winter planting, quite a good germination was obtained in February-March when the temperature ranged from 55.9°F to 72.6°F and the overall germination for this planting varied from 33.9 to 43.4 percent in different years. The crop planted in March (spring) completed its germination by the end of April and during this period the minimum soil temperature ranged from 62.3°F to 83.4°F. The percentage germination was 38.7 to 47.4 in this case. Clements[4] recorded that soil temperature slightly above 70.0°F was nearly marginal for germination. Below this limit there was a decrease in percent germination and an increase in the time of emergence. His findings that there was decrease in percentage germination at a temperature below 70.0°F. is, however, not supported by the results recorded in case of winter and spring plantings in these studies. In the case of early summer planting, the crop completed its germination in about five weeks period, when the minimum soil temperature varied from 75.2°F to 92.6°F and the germination ranged from 30.9 to 37.8 percent. Leake[5], while reviewing the work on sugarcane, stated that germination was slow below 70.0°F and increased upto an optimum within temperature of 88.0°F to 97.0°F. The early summer planting with a minimum soil temperature varying from 75.2°F to 92.6°F in our case, resulted in lower germination than the spring planting under the soil temperature ranging from 62.3°F to 83.4°F. Thus, the optimum temperature worked out by Leake does not hold good for the conditions in this State. Rosenfield[6] carried out plantings at regular intervals all the year round in the southern hemisphere and found that March to May plantings suffered severely from frost in June, and plantings made from 15th July to 15th September gave better results. Under Punjab conditions, planting of cane from end of February to end of March constitutes the optimum time.

Tiller production was more in autumn and winter planted crops than in spring and early summer plantings. It was the poorest in the early summer planted crop and the cane formed shoots did not attain normal height. There was, however, higher mortality of tillers where tiller production was higher and final tiller counts in November showed 44.6 percent tiller mortality in autumn, 42.6 percent in winter planting, 38.4 percent in spring planting and 10.1 percent in the case of early summer planting.

Verret and Mclennan[7] found that shortening the duration of the daily exposure to light results in decreased tiller formation. The lower tiller production in early summer planting when the days were longer, resulting in longer exposure to light, as compared to that recorded in autumn and winter plantings, when the days were short, does not support the findings of the above workers and it appears that both light and temperature during the duration of the tillering phase play an important role in tiller production. In Formosa, Sun and Chou[8] found that cane planted in autumn attained its maximum tillering about March, while spring planting reached its maximum about May. In the case of seasonal plantings described in this paper, the autumn planted crop attained its maximum tillering in April-May and spring planted crop about the end of June. Tillering phase under Punjab conditions in the case of different seasonal plantings, reached its maximum about a month later than in Formosa due probably to differences in weather conditions.

Growth studies in the case of seasonal plantings have revealed that out of the total growth made by the plant, about 15-17 percent growth is put in during hot weather (April-June), 73-75 percent during the grand growth period (July to September) and about 10 percent in the postmonsoon period (October-November). The mean temperature at Jullundur during hot weather ranges from 90°F to 94° F. Apart from the fact that during the early phase of growth, the plant directs its energies towards tiller production, the high temperature appears to be equally responsible for low rate of growth (15-17 percent) in this period. Verret and Das[9] in their studies on the rate of cane growth at various ages found that very little growth took place at a temperature below 60.0°F. Such conditions prevail in this State during November and the lesser growth (about 10%) in October by the plants in the case of all plantings, when the mean atmospheric temperature varies from 60.0°F to 75.0°F, supports the findings of the above authors. The temperature of 83.0°F to 88.0°F with high humidity during July to September was found to provide favourable conditions for cane growth.

In the matter of final tonnage, autumn, winter and spring plantings are alike but these plantings have given significantly higher cane yields than early summer planting both under Jullundur and Gurdaspur conditions. Autumn and winter plantings, particularly the former, remains on the land for about 5-6 months more than the spring planting. In addition, due to comparatively less growth of the crop at its planting time, about 25 to 30 percent more cane area is required for seed purposes in the case of autumn planting as compared to that required for the spring and winter plantings. In the case of winter planting, however, the cane seed is automatically saved from the ill-effects of frost, generally recorded about the end of December and in January.

SUMMARY

An experiment with four seasonal plantings and two rotations was conducted at Jullundur and Gurdaspur in the Punjab for four crop cycles. The object of these studies was to find out if longer duration of the crop could improve yield and juice quality under Punjab conditions. The findings briefly are—

(1) Soil temperature plays an important part in the germination of buds. A minimum soil temperature of 62.3°F to 83.4°F has been found optimum for germination of buds. Autumn planted crop completed its germination in five-six weeks after planting before the onset of winter. The buds in the case of winter planting remained dormant for six-eight weeks after planting due to low temperature and the germination in this case started in February-March when minimum soil temperature ranged between 55.9°F to 72.6°F. Spring planted crop also completed its germination phase in five-six weeks and gave the highest percent germination. Germination in the case of early summer planted crop was the lowest due to comparatively higher soil temperature 75.2°F to 92.6°F, but in this case, the germination phase was completed within four-five weeks.

(2) Application of 30-40 lbs. of 5% BHC dust in furrows at planting of sets has been found necessary to ward off white ant attack, especially in the case of autumn and winter plantings. The stand of the crop, particularly in autumn planting, was affected adversely, when this treatment was not accorded.

(3) Autumn, winter and spring plantings produced larger number of tillers per clump as compared to the early summer planting. The tiller mortality percentage was also higher in the former three plantings, but even then the number of canes per stool, was still in favour of autumn, winter and spring plantings.

(4) In the case of different seasonal plantings, the plants entered into active growth phase during monsoon period and added 73-75 percent of the total growth. In the formative stage, i.e., in hot weather, only 15-17 percent growth was added and only about 10 percent growth was added in the post-monsoon period. While the linear growth was almost alike in the case of autumn, winter and spring plantings, it was about 9.4 percent higher than that attained by the early summer planted crop, besides there being more tillers in the former three cases.

(5) Barring the Indian clover, as a catch crop, the other catch or intercrops sown with cane in different rotations showed rather depressing effect on cane yield. The additional income from such crops did not balance the loss in cane yield resulting in comparatively low gross income. Of the two main rotations, the one, where cane comes after fallow, has been found conducive to high cane yields and the four years data are significantly in favour of this rotation.

(6) Barring the cases of severe incidence of cane pests like Top Borer, in a particular year, different years during which this trial was conducted did not show differential effect on the final cane yield.

(7) The cane yields were significantly in favour of autumn, winter and spring plantings. The average four years yields at Jullundur were 755.7 maunds for autumn, 745.2 maunds for winter, 717.9 maunds for spring against the yield of 535.5 maunds in the case of early summer planting. The net average income from cane or cane plus catch or inter-crop was Rs. 529·7 to Rs. 616·4 per acre in the case of autumn, winter and spring plantings, as compared to Rs. 316·9 of early summer planting.

(8) The quality of juice was not found to vary materially in the case of different seasonal plantings. While the results are rather suggestive of slight early maturity in the case of autumn planting, the longer duration of the crop even in this case, did not bring about a marked improvement in juice quality at harvest time.

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DISCUSSION

Dr. Tandon observed that if the planting was delayed, germination was impeded during autumn and planting after rains would afford the advantage of autumn planting. Mr. Girdhari Lal said that in U. P., autumn planting had given 150 maunds more yield with no effect on sugar and the increase in yield was greater with early varieties.

In the absence of the author Dr. Abbot presented the following paper.

Paper

EFFECT OF SEED-PIECE SIZE AND RATE OF PLANTING ON YIELDS OF SUGARCANE, AND OF NITROGEN FERTILIZATION ON YIELD OF SEED-CANE IN LOUISIANA

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In Louisiana it is common practice to use as much as 20 percent of the sugarcane crop for seed cane annually. Unlike many cane-producing countries of the world where discarded portions of stalks, tops, or short seed pieces are satisfactory for planting material, the sugarcane growers in this State plant whole stalks. The amount of whacking or segmenting of the stalks after placement varies with the individual plantation. Use of whole stalks for planting material and the heavy rate of planting found from experience over a period of many years to be necessary in order to obtain a stand of cane, have resulted in costly seed cane requirements. In former years growers chose seed-cane from either old stubble fields or the less productive areas in order to minimize the use of millable cane for planting purposes, but within recent years they have become increasingly conscious of the importance of the quality of seed-cane.

The occurrence of numerous gaps or breaks in the stands of cane in commercial fields points to the importance of planting sound seed-cane in order to ensure a uniform stand which is essential if maximum production is to be realized at minimum cost. It is not uncommon to see fields overrun with weeds because a high percentage of the linear row footage consists of blank spaces or gaps due to poor-quality seed-cane. This heavy weed infestation with the accompanying increase in cost of cultivating and harvesting the crop, and the far more important factor of reduced yield, emphasize the importance of obtaining good stands of cane. Therefore, there is need for field studies of the effect of cultural treatments of seed plots on quantity and quality of seed-cane produced,the rate of planting,and size of seed piece, as related to yields obtained with some of the important varieties now in commercial production.

In previous studies (2) it was found that the amount of seed-cane required to plant one acre under Louisiana conditions ranged from 2.45 tons with small-barrel varieties like C.P. 36/105 to 4.70 tons with large-barrel varieties like C.P. 44/145 when planting "two running stalks and lap", which is the customary procedure on most plantations. Heavier rates of planting require relatively more seed-cane, depending on the number of stalks placed per linear row footage.

With varieties in commercial culture in Louisiana during the period 1933 to 1936, Arceneaux (1) found that seed pieces of 5 "eyes" or buds gave maximum yields of cane and sugar per acre, but that shorter pieces gave a higher percentage of germination. He concluded that some practices which stimulated germination actually resulted in lower yields of cane.

The present study was started in 1949 with C.P. 36/13, C.P. 36/105 and C.P. 44/101. In 1951, C.P. 36/13 was replaced with C.P. 44/155. Cane yields and stand counts obtained with C.P. 36/105 and C.P. 44/101, the only two varieties that extend over the four-year period, are included in this report. Since these two varieties occupy over 65 percent of the Louisiana sugarcane acreage at the present time, it is believed that the information obtained from this study should be of much value to the Louisiana growers by helping them to make the most effective use of their seed-cane.

EXPERIMENTAL TECHNIQUE

A 2x3x2 split-plot design experiment was used with 2 seed-piece sizes, 3 rates of planting, and with seed taken from plots fertilized with two levels of nitrogen superimposed on each of 3 varieties, with the variety treatment as the main block. Each sub-plot measured 18 feet by 20 feet or approximately 1/120-acre in size, and conversion factors for calculating yields of cane and number of shoots per acre as given in Tables II,III, and IV, were carried to three decimal places. The experimental plots were cultivated alike and uniformly fertilized with 40 pounds of nitrogen in plant cane, and with 60 pounds in first stubble. Two replications of each variety, or main block, were used each year over a period of 4 years so that there were 4 plant cane crops and 4 first-stubble crops, or a total of 8 crops. The tests were planted on August 1 each year on light soil of the Mhoon silt loam type.

Seed pieces were cut into segments of 3 and 5 "eyes" or lateral buds at planting time, each eye being carefully inspected so as to eliminate as nearly as possible all damaged ones. In order to avoid bias and to minimize any possible effect of polarity on germination the starting point was alternated for each stalk. For example, in the case of 2 stalks each 11 joints in length, three 3-eye pieces were taken from the lower part of one, discarding the 2 uppermost joints, while three 3-eye pieces were taken from the upper part of other, discarding the 2 lowermost joints. The same procedure was followed in preparing the 5-eye seed pieces.

Seed plots for the experiments were fertilized at the usual time in April with ammonium sulphate for the first 3 years and with anhydrous ammonia in the last year. Two levels of nitrogen were used on the seed plots the normal plantation rate of 60 pounds per acre and a heavy nitrogen rate of 300 pounds per acre. Seed cane was taken from either first stubble or summer plant cane grown on light soil. In order to arrive at an estimate of the quantity of available seed-cane in the plots, several representative sections of row 60 feet in length were selected at random and all the stalks suitable for planting were counted and that number converted to number of stalks per acre. The number of joints or internodes on approximately 200 stalks were counted for each variety on August 1 and again on October 1. The number of eyes or lateral buds per acre, which in effect is the amount of planting material, was then determined from the number of stalks per acre and the number of eyes per stalk.

Three rates of planting were tested. R_3, the highest rate with approximately 36,000 eyes per acre, compares with standard Louisiana field practice of planting "two running stalks and a lap", in which case the varieties C.P.36/105 and C.P. 44/101 will average approximately 35,000 to 38,000 eyes per acre, respectively (2). R_2, with 30,000 eyes per acre, is equivalent to 2 continuous lines of cane with no overlapping, and R_1, with 24,000 eyes, is equal to one and one-half continuous lines on cane on the row.

RESULTS

Table I gives the approximate quantity of available seed per acre on August 1 and on October 1 for the normal nitrogen and the heavy nitrogen plots for 4 varieties. The heavy rates of nitrogen increased the number of stalks per acre and the number of eyes per stalk for all varieties on both dates. On August 1 this increase ranged from approximately 10 percent with C.P. 44/101 to approximately 41 percent with C. P. 36/13. The quantity of seed-cane on October 1 was correspondingly increased by heavy nitrogen applications. C.P. 44/101, with approximately 10 percent increase, showed the least response to the heavy nitrogen treatment, and C.P. 36/13, with 41 percent increase, showed the greatest. C.P. 36/105 and C.P. 44/155 responded relatively well to the high rate of nitrogen.

The increase in planting material was due both to a greater number of stalks

TABLE I

SUMMARY OF SEED-CANE PRODUCED IN SUGARCANE PLOTS 6 FEET x 60 FEET FERTILIZED AT TWO LEVELS OF NITROGEN DURING THE PERIOD 1949-52, INCLUSIVE. FERTILIZER APPLIED IN APRIL OF EACH YEAR AND COUNTS MADE ON AUGUST 1 AND OCTOBER 1 OF EACH YEAR

Variety	Year	NORMAL NITROGEN FERTILIZATION (60 pounds per acre)			HEAVY NITROGEN FERTILIZATION (300 pounds per acre)				
		Average number of stalks per acre	Average number of joints per stalk		Average number of stalks per acre	Average number of joints per stalk		Increase of available seed-cane per acre over normal nitrogen	
			Aug. 1	Oct. 1		Aug. 1	Oct. 1	August 1	Oct. 1
								percent	percent
C.P. 36/105	1949	22606	7.13	13.51	26808	7.83	14.70	30.1	29.0
	1950	31808	6.85	12.05	40338	7.92	13.78	46.6	45.0
	1951	33251	7.82	14.53	32960	8.54	14.40	8.2	1.8*
	1952	25918	8.07	13.37	30274	8.29	14.42	20.0	26.0
	Average	28396	7.47	13.36	32595	8.14	14.32	25.1	23.0
C.P. 44/101	1949	37861	6.43	12.27	41273	6.55	12.56	11.0	11.6
	1950	38796	5.68	11.02	39068	6.78	12.89	20.2	17.8
	1951	36227	6.62	12.00	36518	6.97	12.49	6.1	4.9
	1952	30347	6.07	11.47	30492	6.18	12.39	2.3	8.5
	Average	35808	6.20	11.69	36838	6.62	12.58	9.8	10.7
C.P. 36/13	1949	30183	6.78	11.03	34503	7.07	12.94	19.2	34.1
	1950	23413	4.29	10.83	29085	6.07	12.37	75.8	41.9
	Average	26798	5.53	10.93	31794	6.57	12.65	41.0	37.3
C.P. 44/155	1951	27098	6.79	11.81	30601	7.20	12.81	19.7	22.5
	1952	26717	5.25	10.69	30347	5.57	12.18	20.5	29.4
	Average	26907	6.02	11.25	30474	6.38	12.49	20.0	25.7

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*Slight decrease in quantity of available seed-cane.

TABLE II

SHOOT COUNT AND PERCENT GERMINATION IN SEED PRE-TREATMENT × SIZE × RATE OF PLANTING EXPERIMENT. AVERAGE OF 4 PLANT CANE CROSS PLANTED ON AUGUST 1, AND COUNTED ON SEPTEMBER 1 OF EACH YEAR DURING THE PERIOD 1949 TO 1952, INCLUSIVE
(PLOTS 18 FEET × 20 FEET)

	HEAVY NITROGEN FERTILIZATION OF SEED PLOT						NORMAL NITROGEN FERTILIZATION OF SEED PLOT					
	3-eye seed pieces			5-eye seed pieces			3-eye seed pieces			5-eye seed pieces		
	R_1*	R_2*	R_3*	R_1	R_2	R_3	R_1	R_2	R_3	R_1	R_2	R_3
				C.P. 36/105								
Shoot count** ...	223	250	329	165	222	265	168	236	352	157	204	238
Percent germ*** ...	20.6	18.9	21.1	15.3	16.8	17.0	15.6	17.9	22.6	14.5	15.5	15.3
				C.P. 44/101								
Shoot count ...	364	364	528	313	397	497	332	432	481	307	401	485
Percent germ ...	33.7	27.6	33.8	29.0	30.1	31.9	30.7	32.7	30.8	28.4	30.4	31.1
				Average of 2 varieties								
Shoot counts ...	293	307	428	239	309	381	250	334	416	232	302	361
Percent germ ...	27.2	23.2	27.4	22.1	23.4	24.4	23.1	25.3	26.7	21.4	22.9	23.2

*Rate 1 = 1 running stalk with very little lap = 24,000 eyes per acre
Rate 2 = 1½ ,, ,, ,, ,, ,, ,, = 30,000 ,, ,, ,,
Rate 3 = 2 ,, ,, ,, ,, ,, ,, = 36,000 ,, ,, ,,

**Average number of shoots per plot.

***Weighted value based on total number of eyes planted.

per acre and to more "eyes" or lateral buds per stalk in the high nitrogen plots. With only one exception, C.P. 36/105 in 1951, the heavy nitrogen treatment resulted in more stalks per acre and in more eyes per stalk.

Tables III and IV summarize the average annual yields of cane per acre of all treatments with C.P. 36/105, and C.P. 44/101 and for the average of both varieties for 8 crops. The 5-eye seed pieces resulted in higher yields than the 3-eye seed pieces in all but one treatment, in which case, however, the difference was not significant. This was with C.P. 44/101 at the low rate of planting in the normal or low rate of nitrogen treatment. In the average of all tests the 5-eye seed pieces increased the yield over the 3-eye seed pieces by 1.4 tons of cane per acre, a significant value at the 1 percent level of probability. The analysis of variance shows that the mean squares for rate of planting and for size of seed piece are highly significant, and that the nitrogen level and all interactions are not significant at the 5 percent level. The heaviest rate of planting produced significantly higher yields than the lower rates ; differences between the two lower rates were not significant. The two behaved very much alike in this respect as shown by the insignificant meansquare for variety × rate of interaction. The highest rate is comparable with the usual field practice of planting "two running stalks and a lap" or approximately 36,000 eyes per acre. Yield differences due to the two rates of nitrogen on the seed plots in the previous year were not statistically significant but the quality of the seed-cane produced was improved as evidenced by the stimulation in germination.

Table II gives the average number of shoots and percent germination for 2 varieties in each treatment during the period 1949 to 1953, inclusive. Each test was planted on or about August 1, and stand counts made on September 1, or approximately 30 days after planting. It will be seen that at comparable rates of planting segmenting the stalks into 3-eye seed pieces increased the germination, and that the heavy rate of nitrogen of seed plots also stimulated germination. There was also a large difference in germination between the varieties, with C.P. 44/101 emerging much more rapidly than C.P. 36/105.

DISCUSSION OF RESULTS

Results of these experiments with 2 of the most widely grown commercial varieties agree with those obtained by Arceneaux (1) when he conducted tests to determine optimum length of seed piece with varieties which were in cultivation in Louisiana 2 decades ago. He found that cane yields from plots planted with seed pieces less than 5 eyes in length were significantly lower than from those planted with seed pieces of 5 eyes, and that yields of cane from plots planted with whole stalks were lower than from those planted with segmented stalks. In the present study with C.P. 36/105 and C.P. 44/101, yields from 5-eye seed pieces were higher than from whole stalks. (Data not shown).

The average annual increase in yields from the 5-eye seed pieces over the 3-eye length ranged from 0.7 ton with C.P. 44/101 at the low rate of planting to

TABLE III

AVERAGE YIELD OF CANE IN TONS PER ACRE FOR 2 VARIETIES PLANTED AT 3 RATES WITH 2 SIZES OF SEED PIECES FROM SEED PLOTS FERTILIZED WITH 2 LEVELS OF NITROGEN. AVERAGE OF 4 PLANT CANE AND 4 FIRST-STUBBLE CROPS DURING THE PERIOD 1950-54, INCULSIVE (PLOTS 18 FEET X 20 FEET)

Rate of Planting	C.P. 36/105				C. P. 44/101				Average of 2 varieties			
	Pounds of Nitrogen per acre applied on seed plots				Pounds of Nitrogen per acre applied on seed plots				Pounds of Nitrogen per acre applied on seed plots			
	60		300		60		300		60		300	
	3*	5*	3	5	3	5	3	5	3	5	3	5
R_1** ...	26.6	27.1	24.3	26.7	35.3	34.9	33.8	35.7	30.9	31.0	29.1	31.2
R_2** ...	25.2	26.7	26.3	27.4	34.9	36.7	35.6	35.7	30.1	31.7	31.0	31.5
R_3** ...	27.4	28.2	26.6	30.0	36.0	37.9	36.3	38.0	31.7	33.1	31.5	34.0
Average of 3 rates	26.4	27.3	25.7	28.0	35.4	36.5	35.2	36.5	30.9	31.9	30.5	32.2
Difference for $P=0.05$	2.64	2.64	2.64	2.64	2.64	2.64	2.64	2.64	1.87	1.87	1.87	1.87
,, for $P=0.01$	3.47	3.47	3.47	3.47	3.47	3.47	3.47	3.47	2.46	2.46	2.46	2.46

*Seed Pieces of 3 eyes and 5 eyes.

**$R_1=24,000$ eyes per acre.
$R_2=30,000$,, ,, ,,
$R_3=36,000$,, ,, ,,

TABLE IV

AVERAGE YIELD OF CANE IN TONS PER ACRE FOR 2 VARIETIES PLANTED AT 3 RATES WITH 2 SIZES OF SEED PIECES. AVERAGE OF 4 PLANT CANE AND 4 FIRST-STUBBLE CROPS ON PLOTS 18 FEET x 20 FEET DURING THE PERIOD 1950-1954, INCLUSIVE

Rate of Planting		C. P. 36/105			C. P. 44/101			Average of 2 varieties		
		3 eyes	5 eyes	Variety average	3 eyes	5 eyes	Variety average	3 eyes	5 eyes	Variety average
R_1	...	25.5	26.9	26.2	34.6	35.3	34.9	30.0	31.1	30.5
R_2	...	25.8	27.1	26.4	35.3	36.2	35.7	30.5	31.6	31.0
R_3	...	27.0	29.1	28.0	36.1	38.0	37.0	31.6	33.5	32.5
Average of 3 rates*	...	26.1	27.7	26.9	35.3	36.5	35.9	30.7	32.1	31.4
Diff. for $P=0.05$	...	1.87	1.87	1.32	1.87	1.87	1.32	1.32	1.32	0.93
Diff. for $P=0.01$	...	2.46	2.46	1.74	2.46	2.46	1.74	1.74	1.74	1.23

*Diff. for significance between averages of 2 varieties when $P=0.05$—0.76 : $P=0.01$—1.00

2.1 tons with C.P. 36/105 at the heavy rate of planting, with an overall increase of 1.4 tons in the average of the 2 varieties in this study. The increase resulting from any one planting would be 2 to 3 times the above values since 2 to 3 crops are harvested from each planting. From a practical standpoint, then, whole stalks should be segmented if the resulting pieces consist of at least 5 eyes each but should not be whacked if too many 3-eye pieces result from the cutting. Cane planted in early August is usually short and whacking is probably not beneficial and may be damaging, if the stalks are less than 9 or 10 joints in length. Cane planted in the fall should be cut into pieces, but care should be taken to avoid having the pieces less than 5 joints long.

As noted by Arceneaux (1) and in agreement with our observations, an increase in germination is not always followed by an increase in cane yields. Some treatments which have caused an increase in germination have actually resulted in decreased yields. This probably results from other conditions affecting the seed piece during or immediately following the period of over-wintering which is often severe in Louisiana. It is of interest to note that the single exception to obtaining higher yields of cane per acre from the longer seed pieces was the only treatment in which the percent of germination was higher with the longer seed pieces.

The extra 0.5 to 1 ton of cane required to plant at the heavy rate of "two running stalks and a lap", or approximately 36,000 eyes per acre, appears to be justified by the statistically significant 1.5 ton per acre per crop increase in yield of cane over the 2-stalk rate, and the 2-ton per crop increase over the 1½-stalk rate, in addition to the better control of weeds where there is more cane on the row. This latter advantage has become increasingly important under our present system of mechanised cultivation and in the herbicidal control of weed pests. All seed pieces in these trials were carefully placed to avoid breaks in the continuity of the line or lines of cane, but this is not always the case in commercial fields where breaks or gaps often occur in the lines of cane when planting at even heavier rates than 2 continuous stalks. More attention should be given to seed-cane placement in commercial fields.

With the present emphasis on growing seed cane for the control of diseases the increase in quantity of planting material from heavy nitrogen application is of special interest. The $20.00 to $25.00 additional cost for heavy fertilization of the seed plots is justified by the 10 to 41 percent, or 2 to 8-ton, increase in amount of seed-cane produced, especially when the seed plot consists of heat-treated or disease-free seed-cane.

Another consideration is the smaller acreage necessary to produce the seed-cane requirements and the release of more land for the production of mill cane under our present acreage control programme. The quality of the cane for milling purposes was not determined and the effect of heavy nitrogen application on sucrose and purity is not known. However, the recommendation for heavy rates of nitrogen applies only to fields intended for planting purposes where any possible depression in sucrose and purity level would not be important.

SUMMARY

Heavy rates of planting found to be necessary under Louisiana conditions and the common occurrence of blank spaces, or gaps, in sugarcane stands point to the importance of giving special attention to the production and preparation of cane for planting as well as to the quantity of seed-cane required for maximum yields per acre. Results of an experiment to study the problem are presented.

Two seed plots of the varieties to be tested were fertilized at the rate of 60 and 300 pounds of nitrogen per acre, respectively, and the seed-cane produced was segmented into 3-eye lengths and 5-eye lengths prior to planting. Three rates of planting were used : rate 1 with approximately 24,000 eyes per acre ; rate 2 with 30,000 eyes ; and rate 3 with 36,000 eyes per acre. Rate 3 is comparable with the commercial practice. All experiments were planted on light soil on or about August 1 of each year.

Plots receiving 300 pounds of nitrogen produced 10 to 41 percent more seed-cane than those fertilized with 60 pounds. There was a difference in varietal response to nitrogen. This response was measured on August 1, when seed-cane was taken for summer planting, and on October 1.

Yields of cane per acre were significantly higher in plots planted with 5-eye seed pieces than in those planted with 3-eye seed pieces, although the opposite was true in percent of germination in the fall. The heavy rate of planting yielded significantly more cane per acre than the 2 lower rates. The increase in yields, together with the more effective control of weeds resulting from a continuous stand of cane, justifies the heavy rate of planting.

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Mr. A.R. Khan presented the following paper.

Paper

IRRIGATION CUM NITROGEN CUM DEPTH OF CULTIVATION RESPONSES OF SUGARCANE

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INTRODUCTION

Of the factors affecting crop production, cultivation, irrigation and manuring together form a major trio, having the most pronounced effect on the yield of a crop. With the harnessing of mechanical power for crop production during the last century, farmers were tempted to plough deep. Several experiments have, however, been conducted in different parts of the world to determine the optimum depth of ploughing for different crops. Hume (1943), Kuron (1948), and Ivanov (1950) noted the beneficial effects of deep ploughing to consist of deeper root penetration, better moisture availability and resultant increased yields. Browning etal (1944) observed that fertilized plots require deep tillage to produce superior responses in corn yield. On the other hand Keene (1931), Turner (1941), Doneen (1947), and Russell (1948, 1950) did not obtain any increase in yield from deep cultivation. Torstensson (1944) found no consistent effect of depth of ploughing on yield. Patawardhan (1948) found no difference in cane yields as between medium (8″-9″ deep) and deep (11″-12″) ploughings. Kanitkar (1944) noticed that the beneficial effect of deep cultivation decreased with the number of years.

Recent work on tillage in India has shown similar results. Khan and Mathur (1954) reported that in case of both maize and wheat, ploughing deeper than 5″ was not advantageous. They also observed that on lands free from weeds the effect of inversion was not marked. Misra and Khan (1954) reporting the results of a three year experiment on sugarcane observed that neither the average out-turn of cane, nor the average sucrose percentage in juice had been significantly affected by the different depths of ploughing. Thus it is seen that the question of depth of cultivation is still an unsettled one. But in general it may be inferred that depth of cultivation does not have any great influence on the yield of crop and that, as noted by Khan and Awasti (1954), good results would accrue if the seed bed was prepared just to loosen the soil for good germination of seed and for eliminating competetion from vegetation. Irrigation is one of those arts which is being practised by farmers from times immemorial and into which research is only a late comer. Scientific research on irrigation doses and intervals has, however, resulted in valuable information. Thus Rege (1944) reported that optimum water requirement for January planted sugarcane at Padegaon farm

(Bombay State) was 95 acre inches and that this quantity was best supplied at 10 days' intervals. Work in Uttar Pradesh has shown that water requirement for sugarcane in terms of number of irrigations varies for western, central and eastern zones both in the pre-monsoon and post-monsoon periods. At Anakapalle (Andhra) (1951), though irrigation once in 12 days increased the yield of cane, it was economical to irrigate once in 18 days. Further south at Gudiyattam (1951) irrigation given at intervals of 6, 12 and 18 days produced similar results. According to Williams (1939) in British Guiana there is no advantage in irrigating cane more frequently than once in 28 days (when the rainfall in the period has not exceeded 2 inches). Wadsworth (1954) states that work in Hawaii has shown that, (a) cane yields are smaller on plots receiving delayed irrigation, (b) juice quality is better in those plots and (c) there is no significant difference in tons of sugarcane produced per acre between irrigation at wilting point and irrigation at 4 or 8 days intervals after the wilting point is reached. Work at Padegaon has also indicated that at higher levels of manuring more water was necessary for highest yield of sugar per acre. On an average, combination of 115 acre inches with 300 lbs. nitrogen per acre for the January planted crop and 115 acre inches and 450 lbs. nitrogen per acre for July planted crop had shown the best response, (Rege 1954). Mathur and Haider (1940) also obtained similar results at Shahjahanpur. However, the interactions of irrigation and nitrogen in 3 to 6 irrigations and 0 to 200 lbs. nitrogen ranges were non-significant (Mukherji and Verma 1950). Thus it is seen that irrigation doses and intervals are largely bound up with the duration of the crop, the soil type in question and the nutrient status of the soil. Outstanding responses to yield have, however, been obtained with nitrogenous fertilization at all the sugarcane research stations in India. The optimum dose of nitrogen for sugarcane, however, varies from tract to tract. In general it is higher in Southern India where cane grows more vigorously under the tropical conditions.

Khanna (1948-49) in Bihar obtained highest yields from a combination of 80 lbs. nitrogen and 150 lbs. phosphate per acre. At Shahajahanpur, a dose of 100 lbs. nitrogen seems to be optimum while at Delhi, Misra and Khan (1954) found that a dose of 80 lbs. nitrogen was more profitable than its double dose. Raheja (1951) reported that highest net yields were obtained either with 150 lbs. dose of organic nitrogen or 100 lbs. dose of ammoniacal nitrogen. In South India, about 200 lbs. nitrogen per acre appears to be an optimum dose at Gudiyattam while in Bombay Deccan increasing responses upto 400 lbs. has been obtained.

Borden (1944) in Hawaii reported that for a plant crop no advantage appeared to accrue under nitrogen doses beyond 150 to 175 lbs. Landrau and Samuels (1954) observed that the use of 125 lbs. of nitrogen produced a striking increase in sugar per acre. Doubling the 125 lbs. of nitrogen dose did not give as great an increase in yield as did the first treatment.

In view of the above varied results obtained in different parts of the world, it was considered worthwhile to lay out an experiment to study the effects of varying levels of irrigation and nitrogen with different depths of cultivation of sugarcane under Delhi conditions.

MATERIAL AND METHOD

The experiment was conducted on the loamy soil of Delhi. The recorded monthly rainfall for the season 1954 when the experiment was in progress was as shown below.

March	..	0.46″
April	..	—
May	..	0.74″
June	..	0.25″
July	..	12.05″
August	..	0.89″
September	..	4.68″
October	..	8.25″
November	..	—
December	..	—
Total	..	27.32″

The experiment was laid out under a split plot design involving the following treatments with regard to depth of cultivation as main plots with nitrogen and irrigation treatments coming in sub-plots as detailed below.

Main plots:

C_0—Cultivation with Deshi plough (non-inversion) 4″-5″ deep.
C_1—Cultivation with tractor plough (inversion) 6″ deep plus disc grubbing.
C_2—Cultivation with tractor plough (inversion) 10″ deep plus disc plus grubber.

Sub-plots:

I_1— Irrigation at 10 days intervals
I_2— ,, at 15 days intervals
I_3— ,, at 20 ,, ,,
N_1— Ammonium Sulphate at 80 lbs. N per acre
N_2— ,, ,, at 120 lbs. N ,, ,,
N_3— ,, ,, at 160 lbs. N ,, ,,

In all there were 27 plots constituting three replications of each of the 9 treatments. Net plot size was 1/71.12 of an acre. Sugarcane variety used was Co. 647. A basal manurial dose of 10 tons of farmyard manure was applied to the entire plot before preparatory tillage.

Cultivation under treatment C_0 was done throughout with local country plough whereas in C_1 and C_2 it was done by tractor implements. Ammonium sulphate was applied in two equal split doses—one at the beginning of May and the other at the beginning of July. Number of irrigations was worked out separately for both pre-monsoon and post-monsoon periods. Pre-monsoon irrigation started with an initial soaking dose on the 28th April and was closed after the 7th July due to onset of monsoon. The post-monsoon irrigation was applied between the 1st and 16th of September. The total number of irrigations given under different irrigational treatments were as follows :—

	Pre-monsoon	*Post-monsoon*	*Total*
I_1	7 irrigations	1 irrigation	8
I_2	4 ,,	1 ,,	5
I_3	3 ,,	No ,,	3

The above are exclusive of two irrigations common to the entire crop, the first being applied on the 28th April and the second on 1st September. Water supplied at each irrigation was 3 acre-inches. Thus excluding rainfall (27.32 inches), the total quantity of water supplied was as follows :—

	Quantity of water supplied
I_1	30″
I_2	21″
I_3	15″

In what follows, responses to the above treatments, both individually and in various combinations, have been discussed.

EXPERIMENTAL RESULTS

Statistical analysis of yield data of stripped canes (Table I) shows that the depth of cultivation had no significant influence on yield.

TABLE I

YIELD OF STRIPPED CANES IN MDS./ACRE

Treatments	Yield in mds./acre
C_0	835.6
C_1	840.4
C_2	950.2
SE (mean)	±51.9
F test	Not significant
I_1	880.5
I_2	876.7
I_3	869.0
SE (mean)	±17.5

F test	Not significant
N_1	872.1
N_2	879.2
N_3	874.9
SE (mean)	±17.5
F test	Not significant

All the same, the beneficial effect of deeper ploughing is apparent. Mean responses to different irrigation intervals and nitrogen intervals were also non-significant. However, yield increases due to N_2 and N_3 over N_1 were significant under treatment C_2 (Table II)..

TABLE II

AVERAGE YIELD OF STRIPPED CANE IN MDS./ACRE

	C_0	C_1	C_2
N_1	850.2	884.3	881.8
N_2	822.1	808.8	1006.9
N_3	834.7	828.1	979.3
F test	Singificant at 5%		
C. D.	84.0 mds./acre		

Higher order interactions depicted in Table III would also indicate good responses to high nitrogen levels in conjunction with ploughing to 10″ depth.

TABLE III

AVERAGE YIELD OF STRIPPED CANE IN MDS. PER ACRE (CULTIVATION x IRRIGATION x MANURING)

	I_1			I_2			I_3		
	N_1	N_2	N_3	N_1	N_2	N_3	N_1	N_2	N_3
C_0	845.5	810.7	890.2	736.6	854.3	829.5	941.8	801.2	784.3
C_1	988.3	794.0	803.3	901.0	774.6	849.4	763.6	857.8	831.6
C_2	837.5	988.1	967.3	986.1	998.7	933.6	821.9	1033.9	985.0

F test Significant at 5%.
C.D. at 5% : 145.6

DISCUSSION

Of the various important factors affecting plant growth, the tilth of the soil, the water and the nutritional requirements of plants can be controlled by farmers. They exert their individual as well as collective influence on the final yield of a crop.

The difference in yield of cane (Table I) due to variation in tilth as produced under different depths of ploughing is not significant; all the same, highest yield has been obtained from 10″ deep cultivation. Doneen (1947), Russell (1950), Patwardhan (1948), Khan and Mathur (1954), and Misra and Khan (1954) also got similar results. Thus it may be concluded that though the requirements for preparing seed bed for sugarcane can successfully be fulfilled by a country plough, deep cultivation under certain conditions may help to boost yield.

Since growth is largely a process of cell elongation and cell multiplication, the importance of water is evident. But water differs from plant nutrients like nitrogen, phosphorus, etc., in that, a huge quantity of it is absorbed and rapidly lost rather than retained in the plant body.

The popular conception that there existed for each soil type an "Optimum" moisture content, at which a given species of plant would display its maximum growth is no more tenable. This conception was given up after the classic studies of Briggs and Shantz (1913). The validity of results obtained by these investigators has been corroborated for sugarcane by Shaw and Swezey (1951), Wadsworth (1932) and Das (1930).

Wadsworth and Das (1932), Shaw and Swezey (1937) reported that the growth of cane was equally rapid between the critical soil moisture contents. In this study it has been observed that cane crop has never been subjected to severe soil moisture stresses. Irrigation at 10 days interval had given the highest yields. This was depressed when the interval was prolonged. But the difference was not found statistically significant. In all 5 irrigations were given to the crop under a 20-day interval, which seemed to be the optimum for sugarcane in this tract. Similar results obtained in Uttar Pradesh confirmed this fact.

Sugarcane universally responds to nitrogen and more so in India where the soils are known to be deficient in this plant food, Das and Cornelison (1936) and Cornelison and Cooper (1940) recorded rapid increase in height of cane and in the number of suckers, as a result of nitrogen application. They also noticed that excess of it might take heavy toll, producing sometimes less number of canes than a moderately high application. Thus it seems that in the nitrogen nutrition of sugarcane there is an optimum limit beyond which, the response to higher dressings of nitrogen may not be proportional to the dose applied. Khanna (1948-49), Mohan Rao and Parthasarathy (1949), Mukherji (1951), Raheja (1951), Rege *et al* (1944, 1954), Misra and Khan (1954), working in different parts of India and Borden (1944) in Hawaii and Landrau and Samuels (1954) in Puerto Rico found different optimum dressings of nitrogen for the cane crop. From the results presented here it seems that 80 lbs.N, as ammonium sulphate with a basal dose of 10 tons of F.Y.M. per acre, is the optimum dose for sugarcane in Delhi. These results corroborated the earlier findings of Misra and Khan.

The interaction between irrigation and nitrogen is not significant. Similar results were obtained by Mukherji and Verma (1950). Cultivation and nitrogen together show a significant effect on the cane crop. The association of heavier nitrogen application with deeper cultivation (10 inches deep tractor ploughing) increased the yield. Browning *et al* (1944) also obtained similar results.

CONCLUSION

Results of a study on the interaction between irrigation intervals, nitrogen doses and depth of cultivation revealed the following facts:

1. Ploughing with country plough was found to be as good as tractor ploughing.
2. Irrigation at 20 days interval appeared to be sufficient for raising a good crop of sugarcane in Delhi.
3. A dose of 80 lbs. N per acre was found to be optimum.

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DISCUSSION

In reply to a question by Mr. Girdhari Lal, the author said that the different depths of ploughing could be suitably adjusted under conditions of mechanical cultivation without introducing gross variations in the level of the field.

WEED CONTROL

Dr. Rochecouste presented the following paper.

Paper

OBSERVATIONS ON NUTGRASS (CYPERUS ROTUNDUS L.) AND ITS CONTROL BY CHEMICAL METHODS IN MAURITIUS

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INTRODUCTION

Nutgrass, *Cyperus rotundus L.*, known in Mauritius as 'herbe a oignons' is one of the most troublesome of perennial weeds of sugarcane fields in the sub-humid and humid regions of the island. Owing to the rapid and efficient method of propagation by means of an extensive system of underground rhizomes and tubers its eradication presents a serious problem to sugarcane growers. The usual method of control has been forking and removal of tubers by hand. Although this practice has given satisfactory results in the case of small areas yet it is impracticable on areas where nutgrass has been thoroughly established. Further, this method has also its limitations as it is difficult to remove all the tubers from the soil by hand and those that remain, re-infest the field in the months following the forking operation.

Preliminary investigations on the use of herbicides for the eradication of nutgrass in Mauritius were started in 1946. Since then a number of selective and non-selective weed killers have been tested with a view to determining their efficacy and the best mode of application.

ECOLOGY AND DISTRIBUTION

The cane lands of Mauritius can be conveniently classified into three main zones : sub-humid (less than 50″ rainfall), humid (50″ to 100″) and super-humid (more than 100″). Nutgrass occurs throughout these regions but its abundance varies and it is of interest to describe the ecological status of the weed in the different zones.

(1) In the sub-humid zone the succession in the weed flora towards a plant community where nutgrass occurs as a co-dominant species is rather rare. In such localities this Cyperaceae generally grows in association with annuals and perennials such as : *Bothriochloa pertusa*, *Rhynchelytrum repens*, *Parthenium hysterophorus*, *Trichodesma zeylanicum*, *Cenchrus echinatus*, *Echinochloa colonum* and *Sida spp.* The grand period of growth being the warmer and wetter months of the year, competition for light is probably the factor limiting the spread of

nutgrass for a great difference in height exists between this weed and the other weed species. The perennial weeds, *Cyncdon dactylon* and *Paederia foetida* also contribute to check considerably nutgrass growth in these regions for wherever they grow the weed can hardly maintain itself owing to the dense top growth formed by these two species.

(2) In the humid zone nutgrass attains its full development, it occurs frequently in local societies with weeds such as *Amaranathus caudatus*, *Solanum nigrum*, *Argemone mexicana*, *Euphorbia hirta*, *Oxalis latifolia and O. corniculata*, *Sonchus asper*, *Bidens Pilosa*, *Siegesbeckia orientalis*, *Phyllanthus spp.* However pure stands of the weed are not frequent except in the irrigated lands of these regions. The only perennial weeds that can suppress its growth and spread in these areas are *Cynodon dactylon* and *Artemisia vulgaris.*

(3) In the super-humid zone, pure stands of this weed in canefields are rare. It is usually found growing in local societies of annual and prerennial weeds including such species as, *Ageratum conyzoides*, *Paspalum paniculatun* and *P. nutans*, *Oxalis latifolia* and *O. corniculata*, *Kyllinga polyphylla* and *K. monocephala*, *Pycreus ferrugineus*, *Cyperus tuberosus* and *Digitaria spp.* Competition between the species is so active that dominance by one is rarely attained. However, when *Phalaris arundinacea* and *Hydrocotyle bonariensis* occur in such societies, there is a biological shift in their favour and nutgrass growth and spread is greatly checked.

MORPHOLOGY AND DISPERSAL

The morphology of *Cyperus rotundus* has already been fully described by Smith and Fick (1937) and Andrews (1940). It is only necessary therefore to briefly summarise the main botanical features of the plant. This *Cyperaceae* consists of a rosette of linear leaves borne on a stem-like structure which terminates below the soil surface into a tuberous enlargement called the basal bulb. The underground portion of the plant is made up of roots, tubers and rhizomes. The basal bulb and tubers are connected by the rhizomes which are wiry and black when mature. Tubers are small, fleshy and consist of nodes and internodes with buds and scale leaves at the nodes. When a bud sprouts it gives rise to a rhizome which may either terminate into another tuber or may grow towards the surface eventually producing a new aerial growth. The inflorescence is a panicle made up of umbel-bearing flowering stalks and the seeds are small brown achenes.

In Mauritius the plant flowers profusely in the warmer and wetter months of the year, that is, from September to about April. Dispersal by seeds, however, seldom occurs because the plant rarely bears fertile seeds. Propagation of the plant occurs mainly by means of its underground parts which are disseminated in the field during agricultural operations.

DISTRIBUTION OF TUBERS IN THE SOIL

Cane fields with pure stands of nutgrass in the interlines were selected at Rose-Belle, Pamplemousses and Reduit, three localities differing in soil types and climate as shown in Table I.

TABLE I

METEOROLOGICAL AVERAGES AND SOIL TYPES

Locality	Soil Group	Soil Type	Mean Ann. Rainfall inches	Mean Max. Temp. °C	Mean Min. Temp. °C	Mean Relative Humidity
Reduit	Humic latosols	Reduit bouldery clay	63.5	25.3	18.1	76%
Pamplemousses	Humic latosols	Richelieu bould clay	57.8	27.0	19.5	75%
Rose-Belle	Lithosol	Rose-Belle gravelly Light clay	143.0	—	—	—

Plots 2½ ft. square were dug, the soil removed at 3, 6, 9, 12 and 18 inches depth and washed through a sieve and the tubers counted. No tuber was found in all the three localities at depth below 18 inches.

Table II and Figure 1 show the distribution of tubers at different levels.

TABLE II

	Reduit		Pamplemousses		Rose-Belle	
Depth (inches)	Total No. of tubers per pit	No. of tubers in %of total	Total No. of tubers per pit	No. of tubers in %of total	Total No. of tubers per pit	No. of tubers in % of total
0 — 3	1675	47.3	338	57.9	185	79.1
3 — 6	950	26.8	185	31.7	38	16.2
6 — 9	750	21.2	49	8.4	6	2.6
9 —12	129	3.6	7	1.1	2	0.8
12 —18	36	1.1	5	.9	3	1.3

With reference to Table II and Fig. 1 it is seen that the greater number of tubers is found in the first 6 in. depth and it is interesting to note that Andrews in the Cotton Soil of the Gezira made similar observations. Below the 6 in. depth, with the exception of Reduit, there is a rapid fall in the density of tubers.

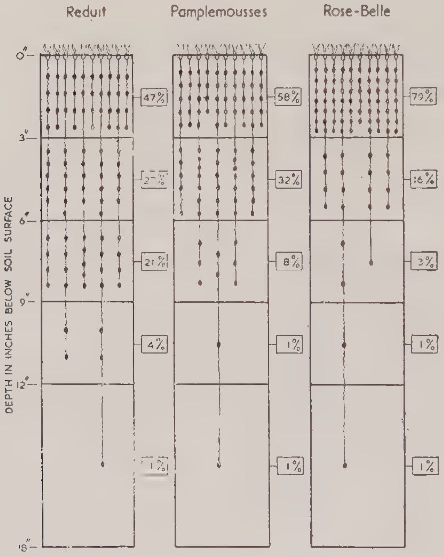


FIG. I- DISTRIBUTION OF TUBERS AT DIFFERENT SOIL DEPTHS

When nutgrass has formed a pure stand in cane fields, on the basis of unit surface area, Reduit is the more heavily infested locality with regard to tuber formation at different levels in the soil.

COMPETITION WITH SUGARCANE

To obtain some information on the deleterious effect of nutgrass on the development of sugarcane the leaves and tubers were weighed separately and analysed for nitrogen, phosphate and potash. The data obtained are presented in Tables III and IV.

TABLE III

GREEN WEIGHT OF TOPS AND TUBERS

Locality	Green Weight kgs. per acre in soil depth of 18″	
	Tops	Tubers
Reduit	2,000	10,000
Pamplemousses	1,365	3,605
Rose-Belle	756	1,239

TABLE IV

MINERAL COMPOSITION IN TERMS OF N, P, and K

	Reduit						Pamplemousses						Rose-Belle					
	% Dry Matter			Kgs./acre			% Dry Matter			Kgs./acre			% Dry Matter			Kgs./acre		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
Leaves	2.56	0.51	3.97	13.3	2.7	20.6	2.15	0.35	3.55	7.6	1.2	12.6	2.69	0.74	5.28	4.3	1.2	8.4
Tubers	1.85	0.28	1.77	35.5	8.4	53.1	1.47	0.27	1.04	21.2	3.9	15.0	1.52	0.65	2.73	6.4	2.7	11.5
Whole Plant	1.94	0.32	2.09	68.8	11.1	73.7	1.60	0.28	1.54	28.8	5.1	27.6	1.84	0.67	3.43	10.7	3.9	19.9

The following comments on the results obtained are necessary :

1. In a medium rainfall region like Reduit, there is little doubt that competition for water by 10 tons of tubers is an important factor; in Pamplemousses, a low rainfall region, this competition may become serious especially in periods of drought.
2. Greater amounts of nutrients are exported by nutgrass in the Reduit soil type and climate, this being related to the larger number of tubers found per unit surface area in that locality.
3. In the super-humid locality of Rose-Belle, the uptake of potassium and phosphorus by the plant is greater, while that of nitrogen is comparable to that of the other two localities.

The quantities of fertilizers exported by nutgrass in the three different localities expressed in terms of sulphate of ammonia, superphosphate and muriate of potash are illustrated in Fig. II from which it may be seen that large quantities of fertilizers are mobilized from the soil to supply the weed. In consequence, the importance of eradicating nutgrass from sugarcane fields does not need to be over-emphasized.

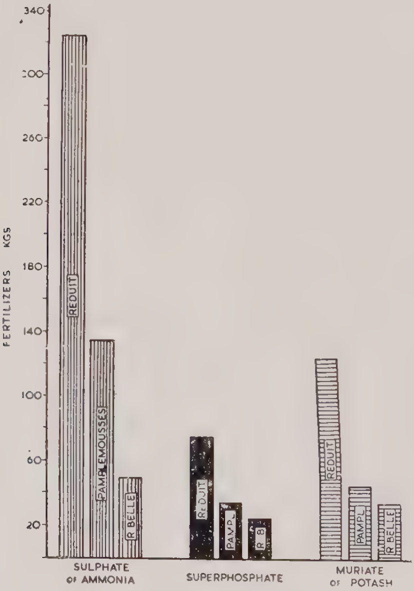


FIG. II- MAJOR NUTRIENTS EXPORTED BY NUTGRASS IN TERMS OF FERTILIZERS

CHEMICAL CONTROL—INTRODUCTORY NOTE

Experiments carried out during the years 1946-1949 established that sodium chlorate and sodium salt of 2, 4-D and M C P A were not effective in controlling nutgrass. Isopropyl ester and tri-ethanolamine derivatives of 2, 4-D killed the existing aerial shoots but vigorous regrowth of the weed occurred about 2 months after that initial killing. Further experimental work to control this weed was carried out subsequently with T C A, ammonium sulphamate, esters and amine derivatives of 2, 4-D and C M U and the results obtained with regard to the herbicidal activity of these weed killers are reported below.

EXPERIMENTAL WORK

1. *Experiment I.*

Plots 20 x 10 ft. selected in pure swards of nutgrass growing in the Reduit soil type were treated in pre and post-emergence of the weed. Pre-emergence plots and control plots in post-emergence were hoed to a depth of about 3 inches and the tubers removed by hands. Density of aerial shoots was established by throwing one-foot quadrat 10 times on each plot and assessment of mortality of aerial shoots was made by the method of awarding points according to the degree of damage sustained by the plant. Gallonnage was kept at the standard rate of 100 gallons per acre.

The results are summarised hereunder in Tables V and VI.

TABLE V

PRE-EMERGENCE TRIAL

Treatments (lbs. per acre)		No. of shoots before spraying in % of control	No. of new shoots six weeks after in % of control	No. of new shoots three months after in % of control
Control		100.0	100.0	100.0
Ammonium sulphamate	— 50	95.2	92.3	102.4
,,	—100	104.1	80.8	98.7
T C A	— 50	93.2	90.8	105.6
,,	— 100	101.1	75.9	102.1
2, 4-D Tri-ethanolamine	—4 lbs. ac/e	94.8	70.5	92.1
2, 4-D Isopropyl ester	—2 ,, ,,	91.6	73.4	90.9

TABLE VI

POST-EMERGENCE TRIAL

Treatments (lbs. per acre)	No. of shoots before spraying in % of control	Six weeks after		No. of new shoots three months after in % of control
		No. of new shoots in % of control	Effects expressed in % of mortality	
Control	100	100	—	100
Ammonium sulphamate— 50	98.9	68.7	39.1	102.1
,, —100	103.6	51.3	45.4	95.9
T C A — 50	94.5	70.4	28.1	106.4
,, —100	93.5	46.5	50.4	93.2
2, 4-D Tri-ethanolamine-4 lbs. ac/e	96.3	15.1	90.5	79.1
2, 4-D Isopropyl ester-2 ,, ,,	102.1	22.1	88.2	83.2

During these investigations it was observed that at the lower rate of application, ammonium sulphamate and TCA did not kill the basal bulbs but only caused a yellowing of the leaves of the weed. Increasing the dosage resulted into about 50 percent kill of the shoots with occasional death of the basal bulbs. The amine and ester derivatives of 2, 4-D were more effective, killing a larger proportion of the basal bulb. However, there were apparently little translocation of the herbicides to tubers directly connected to basal bulbs since a high proportion of these tubers eventually gave rise to rhizomes, which grew upwards terminating in new bulbs.

2. *Experiment II.*

This experiment was laid on the same type of soil and on the same lay-out as Experiment I. Chemically different esters and amines of 2, 4-D were compared in post-emergence of the weed. Three sprayings were carried out at three-monthly intervals. The quadrat method was used for estimating the density of aerial shoots, immediately preceding each spraying. Observations were therefore made over a total period of nine months.

The results obtained are shown in Table VII.

TABLE VII

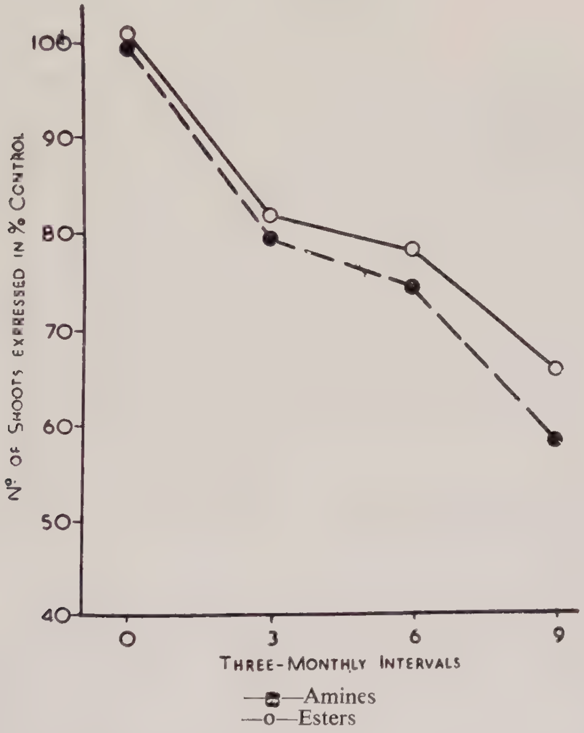
Treatments	No. of shoots in % Control Before spraying	 Before second spraying	 Before third spraying	 Three months after third spraying
Methanolamine—4 lbs. ace/ac	95.0	85.4	78.4	60.9
Dimethylamine ,, ,,	102.6	72.4	70.4	55.2
Di-ethanol methylamine ,,	101.0	77.4	73.4	57.8
Ethyl ester—1 lb. ace/ac	93.0	87.1	82.4	68.1
Isopropyl ester—2 lbs. ace/ac	104.5	80.4	78.6	65.7
Butyl ester ,,	99.3	83.9	78.9	66.4
Butoxy ethanol ester ,,	103.6	76.4	73.4	63.0

The results of these experiments show that repeated applications of amine and ester derivatives of 2, 4-D on nutgrass at three-monthly intervals progressively reduce the density of aerial shoots. The trend in relative toxicity of amine salts and esters is illustrated in Figure III from which it may be seen that the former compounds appear more effective in controlling nutgrass. The dimethylamine salt stands out as being the best treatment and the butoxy ethanol ester proves more effective than the other esters in that respect.

3. *Experiment III.*

C M U was applied at dosages varying from 2 to 16 lbs. per acre in alternate interlines of plant canes about 2 months old growing in the Richelieu bouldery clay soil type. Higher rates of C M U were not used in this experiment because these have been found in other countries to be detrimental to cane growth. The chemical was applied in pre and post-emergence of the weed and the volume of water was kept at the standard rate of 100 gallons per acre. Nutgrass population was assessed by the quadrat method before spraying and three months later.

Fig. III



The results obtained are given below.

TABLE VIII

Treatment	Pre-emergence Density of shoots in % of control		Post-emergence Density of shoots in % of control		Effect on Cane
	Before spraying	Three months after	Before spraying	Three months after	
CMU — 2 lbs./acre	95.0	97.4	97.0	101.4	No effect
” — 4 ”	102.1	103.1	102.7	98.4	”
” — 6 ”	97.8	102.3	101.2	99.5	”
” — 8 ”	101.4	100.1	104.4	102.9	”
” —10 ”	97.9	99.4	96.1	98.4	”

TABLE VIII (*Contd.*)

„ —12 „	102.8	96.2	94.9	104.3	Slight check in growth and pale green coloration of leaves
„ —14 „	96.8	90.4	98.5	95.1	Temporary check in growth partial chlorosis of leaves in some canes
„ —16 „	98.4	85.8	95.4	92.8	„

These preliminary results show that nutgrass cannot be controlled satisfactorily by C M U in sugarcane fields at doses that would not be harmful to cane growth. At the rates of 14 and 16 lbs./acre a check in growth occurred with a partial chlorosis of the leaves in some cases. Such effects, however, gradually disappear and in the three months following the treatment growth had become normal again.

It has recently been found (Loustalot *et al* 1954) that two applications of C M U at the rate of 20 lbs. per acre preceding ploughing can give satisfactory control of the weed but this would not be applicable in sugarcane plantations owing to the deleterious effects of the chemical at such rates on cane growth.

SUMMARY AND CONCLUSIONS

Preliminary experimental work carried out on the eradication of nutgrass by chemical methods showed that :

1. Ammonium sulphamate and T C A are not effective in controlling nutgrass both in pre and post-emergence of the weed.
2. Amine salts and esters of 2, 4-D give an excellent control of the aerial portion but the translocation of the toxicant to the underground organs is apparently very small for regrowth incidence from tubers is fairly high.
3. Repeated applications of amine and ester derivatives of 2, 4-D indicates a trend towards the greater effectiveness of the amines, the dimethylamine standing out as the best treatment.
4. C M U at doses from 2 and 16 lbs. per acre failed to control nutgrass and at the higher rates caused temporary adverse effects on cane growth.
5. Complete eradication of nutgrass was not obtained but it was established that fairly satisfactory control could be achieved by repeated applications of amine and esters of 2, 4-D preferably the dimethylamine salt.

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Dr. Arakeri then presented the following paper.

Paper

STUDIES ON WEED CONTROL WITH CHEMICALS IN SUGARCANE CROP IN THE BOMBAY STATE

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INTRODUCTION

The problem of weed control has confronted the farmers of all ages, and it is more so in an irrigated crop like sugarcane. This problem has been tackled by various methods with different degrees of success. Although chemicals have been employed to control weeds in some crops from the beginning of this century, this method has come in use on larger scale only during the last decade with the introduction of new hormone type herbicides like 2, 4-D and other related compounds. In western countries application of chemicals for controlling weeds has become a regular routine operation in growing some crops. But in India this method of weed control is still in its early stages of development. India has its own problems as regards the use of this method on a large scale to control weeds. Labour is cheap, chemicals are costly and more than all there is a predominance of grassy weeds. It is, therefore, necessary to take all these factors into consideration in developing a suitable method of weed control with chemicals.

It is a well known fact that 2, 4-D is a selective herbicide and post-emergence and pre-emergence are the two principal methods of applying this herbicide. The first method is popular and dependable but it is effective in controlling broad leaf weeds only. To start with, post-emergence method was therefore most commonly adopted.

Possibilities of pre-emergence application were indicated by the results of the studies carried out in England, Canada and the U.S.A. as early as in 1948. Although these studies showed promise of the pre-emergence method of weed control in various crops, it was considered as a hazardous method as late as in 1949 because of the inconsistent results obtained under varying soil and climatic conditions. Arakeri and Dunham (6) studied the reasons for these variations and showed that some of the environmental factors like pH of soil, organic matter content and rainfall after application were mainly responsible for such variable results. Although the reasons for variable results are better understood now, pre-emergence method is still considered as less dependable. However, it has certain advantages. The main advantage is that it may be possible to control broad leaf weeds as well as grass weeds. Therefore, if proper technique of application could be developed, it may be more popular under Indian conditions.

As far as weed control in sugarcane crop is concerned, a number of tests have been carried out all over the world. Nolla (10) has sounded a word of caution in using 2, 4-D indiscriminately in sugarcane crop. His results show that some varieties are more susceptible to 2, 4-D injury than the others, and that in general the sugarcane plant is more resistant when it is below 3 months age. He has also shown that retardation in growth in early stages may be made up later on. Chilton *et al* (9) on the other hand have developed a suitable programme of weed control adaptable to conditions prevailing in Louisiana (U.S.A.). In other countries also, suitable programmes have been developed to control weeds in sugarcane fields. With a view to developing a programme, suitable for conditions obtaining in the Bombay State, work was started on the Poona Agricultural College Farm. In this paper, summary of results of these tests and others carried out at different places in the Bombay State are presented.

In the Bombay State, sugarcane is grown as an irrigated crop. It is planted during different months of the year. Usually the crop is planted either in January or in July or in October. Weeds are more problematic in July and August planted crop than others. At present weeds are removed largely by hand weeding and to some extent by hoeing. Sometimes it becomes difficult to remove the weeds in time due to climatic conditions or due to non-availability of labour. Under such circumstances chemical method is comparatively more useful.

In this State, Bhonsale (8) was the first to use 2, 4-D compound in sugarcane fields. He tried to study the possibilities of controlling *striga*, an angiospermic parasite on sugarcane plant. Side by side he studied the effect of this chemical on other common weeds also. He used 'Fernoxone' (sodium salt of 2, 4-D) as post-emergence spray. He concluded that it is effective in controlling *striga* and some broad leaf weeds but not grass weeds. Later on when the results of the first of the series of experiments taken up at the Poona Agricultural College Farm, were reported in 1951 (2), interest in the chemical method of weed control grew and many investigators started working on this aspect of weed control in sugarcane crop. The results obtained so far are presented under different headings in the following paragraphs.

VARIETAL TOLERANCE

The variety grown on the largest area in the Bombay State is Co. 419. Area under other varieties like Co. 475 and P.O.J. 2878 is negligible. In some centres Pundia variety is also grown to some extent for its *Gul* quality and for sale in the urban areas for chewing purpose. Since Co. 419 is the ruling variety of the State, most of the work is done on this variety. However, some work is reported on other varieties like P.O.J. 2878 and Pundia.

In one of the trials (2) three different chemicals (sodium salt, amine salt and 2, 4-D "Cellosive" sulphate) were sprayed on Pundia variety at the rates of 1 and 2 lbs. in 40 gallons of water per acre. In all the treated plots there was set back in germination (Table I) and growth which persisted upto the end.

TABLE I

NUMBER OF SHOOTS AND WEEDS IN AN AREA OF 30′ x 4′ ON DIFFERENT DATES IN THE PLOTS SPRAYED WITH DIFFERENT CHEMICALS FIVE DAYS AFTER PLANTING, AVERAGE OF FOUR REPLICATIONS, VARIETY PUNDIA

Treatment	Number of shoots on				Number of Annual weeds* 21-23.2.51	
	3.2.51	17.2.51	3.3.51	29-30.4.51	Grass	Broadleaf
Spraying 5 days after planting						
2, 4-D Sodium salt (Fernoxone)						
Check	6.0	33.5	42.5	94.75	164.75	36.0
One lb. acid equivalent	4.25	26.0	39.0	92.0	71.75	18.25
Two lbs. acid equivalent	3.75	22.75	34.0	90.25	29.0	15.50
2, 4-D Amine						
Check	9.25	39.0	45.75	101.0	196.75	57.75
One lb. acid equivalent	6.0	27.5	35.25	92.25	37.5	17.25
Two lbs. acid equivalent	6.25	19.5	26.75	89.75	19.25	13.25
2, 4-D 'Cellosive' sulphate						
Check	11.25	40.25	49.75	95.75	193.75	51.25
One lb.actual chemical	16.0	43.0	51.0	91.75	119.75	38.25
Two lbs. actual chemical	10.25	34.0	45.0	97.0	92.0	54.25

The setback was more pronounced in case of sodium salt and amine salt when 1 and 2 lbs. of acid equivalent was used than in the third chemical when 1 and 2 lbs. of actual chemical was used. On other two varieties (Co. 419 and P.O.J. 2878) only sodium salt was used. In these varieties also there was some setback but not so marked as in Pundia, which however was made up in later stages.

In another test also (4), Pundia was proved to be quite susceptible to all the chemicals tried. Even experimental herbicide I (2, 4-D 'cellosive' sulphate), which

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* Common weeds were—

Grasses— Mainly *Panicum isachne*
Broadleaf— *Commelina Sp., Amarantus Sp. and Euphorbia Sp. and Argemone Mexicana*

it is claimed by the manufacturers' can be used on susceptible crops for pre-emergence spray, was observed to result in a setback in germination and growth (Table II).

TABLE II

NUMBER OF SHOOTS OF SUGARCANE IN AN AREA OF 38′ x 4′ AND AVERAGE HEIGHT OF SUGARCANE PLANTS ON DIFFERENT DATES, AVERAGE OF 4 REPLICATIONS, VARIETY PUNDIA

Treatment	Shoot counts on				Height in cms. on				
	28/2	14/3	28/3	26/8	21/4	19/5	2/6	14/7	29/7*
Check	41	43	42	92	21	27	27	63	67
2 lbs. E. H. I. (2, 4-D cellosive sulphate)	32	39	38	99	17	27	26	58	58
4 lbs. E. H. I.	26	31	32	79	17	25	23	50	55
6 lbs. E. H. I.	25	36	36	78	17	24	26	51	49
1½ lbs. as Fernoxone 2, 4-D sodium salt	24	30	33	85	16	25	28	59	62
1½ lbs. as Kathon E. 40 (ester)	23	31	32	85	19	23	25	46	49
1½ lbs. as Kathon M. 7 (amine)	19	31	30	87	19	23	26	47	59

* Earthing up was done before this observation.

In the third test (5) an attempt was made to examine the possibilities of reducing the injury by reducing the concentration. In this test 1½ lbs. of acid equivalent in the form of amine salt and sodium salt was applied in 50 and 100 gallons of water per acre. As expected this also did not show any improvement as far as injury to Pundia variety is concerned (Table III).

Similar dosages given to Co. 419 showed temporary setback in very early stages only which also was made up later on (Table IV).

TABLE IV

NUMBER OF PLANTS IN AN AREA OF 17′ × 4′, NUMBER OF TILLERS PER PLANT, AND AVERAGE HEIGHT OF PLANTS ON DIFFERENT DATES. AVERAGE OF THREE REPLICATIONS

Treatment							
2, 4-D acid in lbs.	Formulation used	Quantity of water in gals. per acre	Number of plants on			No. of tillers per plant on	Height in cms. on
			15/2	23/2	4/3	15/6	15/6
1½	Sodium salt (Fernoxone)	40	28.0	34.3	36.6	2.2	26.8
1½	-do-	80	28.6	31.0	38.6	2.1	26.1
1½	-do-	120	25.0	29.6	37.0	2.0	26.6
Check	—	—	36.6	38.3	40.0	2.2	27.2

TABLE III

NUMBER OF PLANTS IN AN AREA OF 30′ × 4′, NUMBER OF TILLERS PER PLANT AND AVERAGE HEIGHT OF PLANTS ON DIFFERENT DATES, AVERAGE OF 4 REPLICATIONS, VARIETY PUNDIA

Treatment			Number of plants on			No of tillers per plant on			Height in cms. on		
2, 4-D acid per acre in lbs.	Formulation used	Quantity of water in gals. per acre	15/2	3/2	4/3	14/3	28/5	15/6	14/5	28/5	15/6
1½	Sodium salt (Fernoxone)	50	54.7	73.7	86.2	3.1	3.1	2.5	29.3	32.4	40.8
1½	-do-	100	51.7	69.2	90.0	3.2	3.3	2.2	29.2	31.4	39.3
1½	Dimethyl amine salt (Kathon M-7)	50	50.0	63.7	80.2	3.0	3.1	2.4	28.3	31.9	37.7
1½	-do-	100	47.0	59.5	71.7	3.0	2.8	2.2	23.1	31.7	36.1
1½	Sodium salt (Fernoxone)	50	54.0	74.0	88.5	3.1	3.2	2.1	29.3	31.9	32.2
1½	-do-	100	55.2	66.7	86.2	3.0	2.7	2.3	28.3	29.1	31.8
Check	—	—	90.5	104.7	115.0	3.5	3.0	2.4	30.3	31.4	39.0

These studies conclusively showed that Pundia variety is definitely susceptible to all the 2, 4-D formulations in any dosage and concentration. Other workers (11) and (12) have also confirmed that injury to Co. 419 variety is temporary which is made up at later stages.

FORMULATIONS

Elaborate studies carried out in other countries show that 2, 4-D in ester form is more active, that in amine form is mild and that in sodium salt form it is intermediate. The formulations included in different studies (2) (4) and (5) were sodium salt, amine salt, ester and 'cellosive' sulphate. All chemicals were sprayed at 1½ lbs. of acid equivalent per acre, each time except the last one which was tried in dosages of 2, 4 and 6 lbs. of actual chemical per acre. From weed control point of view no difference was observed. 2, 4-D 'cellosive' sulphate had to be used in dosages of 4 to 6 lbs. to get weed control of similar degree as that obtained with other chemicals at the rates of 1½ lbs. of acid equivalent per acre. Evan from crop injury point of view there was no difference (Table I).

At Padegaon (1) sodium salt alone was compared with sodium salt mixed with Pentachlorophenol (PCP) dissolved in diesel oil. Spraying the mixture of PCP (3 gallons), 2, 4-D (1½ lbs.) and diesel oil (3 gallons) immediately after planting controlled both kinds of weeds to a better degree than when 2, 4-D was used alone. No further tests have been carried out with this mixture.

From these studies, it is clear that there is no difference in different formulations and therefore, the choice of chemical would depend upon the market price per pound of active ingredient or the cost per acre to control the weeds with a particular chemical.

TIME OF APPLICATION AND DOSAGE

Time of application is very important in chemical method of weed control in general and in pre-emergence method in particular. Dosage is important from cost and crop injury point of view. The dosage must be such as to kill the weeds effectively but not injure the crop plant. Lower the effective dosage, better it is from cost point of view.

The initial studies conducted at Poona (2) included various dosages and different times of application. In one of the tests dosages tried were 1 and 2 lbs. of acid equivalent per acre. In another test (2) one pound of acid equivalent was sprayed 2 days, 5 days and 10 days after planting. In both tests, 40 gallons of water was used per acre. The results indicated that 1 lb. was too little from weed control point of view and 2 lbs. was too much from crop injury point of view and spraying after 5 days was better than 2 or 10 days after planting (Tables I and V). It was also shown that second spraying might be necessary to obtain still better control of weeds than that obtained with one spraying.

TABLE V

NUMBER OF CANE SHOOTS AND NUMBER OF WEEDS IN AN AREA OF 20′ x 4′ SPRAYED WITH ONE LB. OF 2, 4-D PER ACRE IN THE FORM OF 'FERNOXONE', (2, 4-D SODIUM SALT) ON DIFFERENT DATES AFTER PLANTING

Days after planting until sprayed	Number of shoots on				Number of annual weeds on 21-23.2.51	
	3-2-51	17-2-51	3-3-51	29-30.4.51	Grass	Broadleaf
Check	8.75	27.75	35.00	89.00	204.75	37.50
2 days	5.00	26.00	32.25	86.25	69.50	18.50
5 days	4.50	24.50	34.25	82.75	49.00	15.25
10 days	9.00	33.00	39.50	86.50	86.50	6.50

Further tests, therefore, included spraying with 1½ lbs. of 2, 4-D acid equivalent per acre and it has proved quite satisfactory. Other trial (3) to determine the proper time of giving these two sprayings showed that it is better to give one spraying 5 days after planting at the time of second turn of irrigation Table VI).

Similar studies have been conducted at other places also. Results of experiments conducted at Padegaon (unpublished) indicate that 1½ lbs. of acid equivalent per acre applied once immediately after planting and second at the time of next irrigation turn is sufficient to get good control of weeds. Tonape (12) has shown that it is better to apply 1 lb. of 2, 4-D acid per acre three times once immediately after planting and the other two at the time of 2nd and 3rd irrigation turns than to apply 1½ lbs. once or twice only. Limaye (11) tried three dosages 1, 2 and 3 lbs. of 2,4-D at every turn of irrigation and at every alternate turn of irrigation. In all, he gave three applications. The results indicate that good control of weeds was obtained in all the treatments irrespective of dosages but, spraying at every turn of irrigation showed comparatively better results than spraying at every alternate turn. In all the cases 1st spraying was given immediately after planting but before irrigation.

From these tests, it can be said that on the whole about 3 lbs. of acid equivalent is necessary to get good control of weeds. As regards time of application, three applications one at every turn of irrigation, including the first one immediately after planting have been proved to be as good or even better than two applications one five days after planting and the second 20 days after planting.

CONCENTRATION

It has been shown that more than concentration, it is the total dosage that is more important in weed control. However, some experiments have been conducted in the Bombay State to find out whether injury to crop plant can be reduced by reducing the concentration. In many of the trials the quantity of water used has been 40 gallons per acre. In one of the tests, 40, 80 and 120 gallons

TABLE VI

NUMBER OF SHOOTS OF SUGARCANE AND NUMBER OF WEEDS IN AN AREA OF 28′ x 4′ AND AVERAGE HEIGHT OF SUGARCANE PLANTS ON DIFFERENT DATES, AVERAGE OF FOUR REPLICATIONS

Treatment	Spraying done			Number of shoots on				Height in cms on						No. of annual weeds 3-3-1952 to 5.3.1952	
	Before planting	Few days after planting	At the time of 2nd turn of irrigation	28/2	11/3	25/3	7/8	29/4	17/5	2/6	13/6	28/6	7/8	Broad leaf	Grass
A. Check	Nil	Nil	Nil	73	73	72	136	32	48	85	112	145	192	124	132
B. Spraying 10 days before planting after giving irrigation	14/1	Nil	Nil	53	57	59	142	27	35	63	79	130	165	22	27
C. Spraying as in B plus 2nd spraying after two waterings after planting *i.e.*, 5 days after planting	14/1	28/1	Nil	47	56	60	144	26	39	68	95	131	179	19	10
D. Spraying as in C plus 3rd spraying after irrigation at the time of 2nd turn of irrigation	14/1	28/1	11/2	56	60	62	144	26	33	58	83	110	160	24	9
E. Spraying as in B plus 2nd spraying after irrigation at the time of 2nd turn of irrigation	14/1	Nil	11/2	55	61	62	139	28	39	73	97	132	176	5	10
F. Spraying after two waterings after planting i.e., 5 days after planting	Nil	28/1	Nil	50	56	60	138	27	37	61	95	139	183	31	25
G. Spraying as in F plus 2nd spraying after irrigation at the time of 2nd turn of irrigation	Nil	28/1	11/2	59	66	68	148	27	38	68	94	132	171	13	4

and in another 50 and 100 gallons of water were used (4) & (5). The results showed no difference either in regard to weed control or in causing injury to crop plant. However. the distribution was better facilitated with higher rates of water per acre than 40 gallons. From this, it is seen that any quantity of water from 40 gallons to 120 gallons may be used depending upon the sprayer that is available for application.

POSSIBILITIES OF REDUCING THE INITIAL SETBACK

It has been shown that the sugarcane crop gets initial setback to a certain degree even if it is a tolerant variety like Co. 419. Some preliminary studies were conducted by Bapat (7) to examine the possibilities of reducing this initial setback by giving some treatments to soil or to seed material. He tried different methods like applying farm yard manure to soil in the furrow just before planting, application of extra dose of ammonium sulphate before planting, and treating the seed material with agallol or lime water. He observed that applying of farm yard manure before planting reduces the initial injury.

CONCLUSIONS

From the results of the tests conducted so far following conclusions can be drawn :—

1. Chemical method of weed control can be adopted successfully in sugarcane crop in the Bombay State. There is varietal difference as regards tolerance to 2, 4-D. Pundia variety is susceptible and it gets permanent setback when treated with 2, 4-D compounds even at very low rates. Varieties Co. 419 and P.O.J. 2878 are tolerant to 2, 4-D treatment. They also get temporary setback but the same is made up at later stages.
2. Any formulation of 2, 4-D is good enough as long as about 1½ lbs. of acid equivalent is applied per acre, at every spraying. If it is 2, 4-D compound of 'cellosive' sulphate, 4-6 lbs. of actual chemical is required per acre per spraying.
3. It is better to give two or three applications at the rate of about 1½ lbs. per acre preferably at every turn of irrigation including the first one immediately after planting. Good results have been obtained even with two applications at the rate of 1½ lbs. per acre once 5 days after planting and the second 20-25 days after planting.
4. Any quantity of water varying from 40 to 120 gallons may be used per acre depending upon the type of sprayer that is available. With ordinary sprayers it facilitates even distribution, if higher rates than 40 gallons per acre are used.
5. The initial setback caused to the sugarcane plants because of 2, 4-D spray, can be further reduced by applying farm yard manure in the furrows before planting sugarcane.

This chemical method of weed control is being adopted on large scale on some of the factory estates in the Deccan Canal Tract of the Bombay State.

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DISCUSSION

Replying to a question by Mr. C. N. Agarwal, Dr. Arakeri said that CMU had not been used so far in India. Mr. King giving his experiences in Queensland said that although adverse effects of weedicides on cane germination had been reported in Hawaii his results with 4 lbs. of the chemical applied as low volume sprays (45 gallons) showed no such deleterious effects except in case of sandy soils. Such deleterious effects were possible on a sandy soil and he wanted to know whether the experiment had been conducted on sandy soil. Dr. Arakeri replied that his experiment related to black clayey soil and although initial germination counts showed a definite set back, differences were not marked after the 8th week stage. Further, the deleterious effects on initial germination were more marked in January planted crop as compared to *Adsali* crop. Dr. Rochecouste doubted if the dose of 3-4 lbs. used would be deleterious at all. Dr. Arakeri replied that the aerial connected nuts were not killed and the chemical was translocated up to only one nut and not upto two nuts and if it could be made to travel upto two nuts regrowth of nut grass could be controlled successfully. He, however, opined that alternate ploughings with 2 to 3 sprayings allowed all the nuts to sprout and get killed with a resultant better control. Dr. Evans giving his experiences of weed control in British Guiana said that germination was greatly impaired by pre-emergence sprays but in case of susceptible varieties like 337/161, the roots primordia were converted to flat bulb like structures. There appeared to be two critical periods for the effectiveness of these weedicides, one immediately after application and the second a week later. Mr. Girdhari Lal mentioned about decreases in yield of cane up to about 0·5 percent by chemicals. Interculture operations removed weeds and brought about light earthing, whereas with chemicals less tillering was observed.

Mr. Khan then presented the following paper.

Paper

STUDIES ON THE RELATIVE EFFICIENCY OF DIFFERENT FORMS AND DOSES OF NITROGEN IN CONJUNCTION WITH MEASURES OF WEED CONTROL ON THE GROWTH YIELD AND QUALITY OF SUGARCANE

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INTRODUCTION

Application of nitrogen is a very important aspect of sugarcane cultivation. Sugarcane has a high nitrogen requirement, and it responds readily to nitrogenous manuring. Rege (1941) concluded that nitrogen fertilization for sugarcane had been a definite necessity throughout India. Rege and Sannabhadti (1944) remarked that all phases of sugarcane growth were favourably influenced by nitrogenous manuring. The Expert Committee on Manures and Fertilizers, Government of India (1953), concluded that average return per lb. of nitrogen was 102.4 lbs. for sugarcane in India.

The application of nitrogen to sugarcane, however, is not an unmixed blessing. With higher nitrogen doses, response per lb. of nitrogen decreases and its application becomes uneconomic ; incidence of lodging increases and the quality of cane deteriorates. Thus, judicious application of nitrogen is of great importance to prevent damaging effects of excessive nitrogen and to obtain an economic return. Obviously, this would need widespread experimentation with different doses of nitrogen on different soil tracts of India.

There are many forms of nitrogenous fertilizers in which nitrogen is applied to the crops. These different forms of fertilizers have different physico-chemical and biological reactions in soils. Due to these reactions they vary in their relative efficiency to different crops. Thus it is necessary to know the best form in which the nitrogen should be applied to a particular crop for maximum advantage.

Weed control is one of the major items of expense in the production of sugarcane. Borden (1944) reported that weeds, when left uncontrolled, reduced the yield of sugarcane in Hawaii by 70 percent or more. Barnes (1953) remarked that weeds took a high place in the list of enemies of the sugarcane crop. If they are not efficiently controlled, the yield of cane and sugar are reduced. Hildebrand (1946) stated that weeds competed for soil nutrients and reduced not only the quantity but also the quality of farm crops. Robbins (1952) stated that weeds competed with crops for water, light and mineral nutrients. The heaviest loss is caused by their competition with crops for the essential requirements. From the above remarks the necessity of weed control is evident.

Among the measures of weed control, the mechanical method of tillage is regarded as the earliest and most important. Robbins (1952) concluded that in majority of cases, some form of tillage is the most practical method of combating annual weeds. Besides the control of weeds, tillage has the extra advantage of stirring the soil, which promotes root development and moisture absorption.

The advent of this century saw the utilization of chemicals as means of weed control. The first substance to be used by a French scientist was Copper sulphate. Copper sulphate belongs to a class of selective contact herbicides, which kills broad leaved weeds with exposed growing points.

Chemical weed control received a new stimulus when the herbicidal properties of the 'Plant Growth Regulators' were discovered by a team of British scientists headed by Blackman in 1940. Among these, 2, 4-Dichlorophenoxyacetic acid (2, 4-D) is among the most effective. Venkatraman (1952) stated that these herbicides were superior to the older ones in that they were inexpensive, selective in their action, harmless to man, animal and soil, non-corrosive and non-explosive. As a result of these features, they have been widely advocated.

Van Overbeek (1946) reported that the most beneficial effect of 2, 4-D as selective herbicide has been found in sugarcane culture. In 1947 he stated that among grasses sugarcane was the least sensitive to 2, 4-D even in early stages. In India the work on 'hormonal weedicides' has not been much. In 1950 a scheme was drawn up by the Indian Council of Agricultural Research for large scale experimentation with these herbicides. Padwick (1948) and Kumar and Solomon (1948) reported the efficiency of 2, 4-D in eradicating Motha (*Cyperus rotundus*), water-hyacinth and certain other weeds. However, the widespread use of these herbicides calls for caution as the botanical composition of weed populations varies from field to field and farm to farm. In view of this, information on the efficiency of herbicides under specific conditions is very necessary. Against the above background, an experiment was started at the Indian Agricultural Research Institute, New Delhi, in 1954-55 to assess the effect of different forms and doses of nitrogen in conjunction with measures of weed control on the growth, yield and quality of sugarcane.

MATERIALS AND METHOD

Three forms of nitrogen, Ammonium sulphate (F_1), Chilean nitrate (F_2) and Calcium nitrate (F_3), three doses of nitrogen 40 lbs. (N), 80 lbs. (N_2) and 120 lbs. (N_3) per acre and three methods of weed control i.e. mechanical control (Hand weeding W_0), application of Dicotox (2, 4-D ester) at the rate of 5 lbs. per acre (W_1), and copper sulphate at the rate of 15 lbs. per acre (W_2) sprayed as an aqueous solution, constituted the variants. Treatments involved (27 in number) were all combinations of the above, replicated twice in a 3^3 partial confounding design with y and z components of the third order interaction being confounded. A basal dose of 10 tons Farm Yard Manure and 80 lbs. phosphate was given to the entire field uniformly at the time of preparation of the field. The gross plot size was 1 45.4 of an acre. The variety used was Co. 312, now in general cultivation in the area.

Observations were recorded on weed population, green and dry weight and botanical composition per square foot area taking 5 samples at random in each plot. The first observation was taken just before the weed control operations i.e. June and thereafter at every 15 days interval till earthing up in the end of July. Further observations were taken once in October and again in March at harvest to know the after effects of weedicides and the weed population throughout the growing season of the crop.

DISCUSSION OF RESULTS

Statistical analysis of the data revealed some interesting trends. Average yield per acre was significantly improved by the mechanical method of weed control over the others, thus proving its efficiency in controlling weeds over the other two methods tested (Table I) . The other treatments, however, did not show significant differences among themselves. Among the three forms, best response was obtained with Chilean nitrate, 120 lbs. dose of nitrogen giving the highest yield with 40 lbs. yielding the lowest.

The mean C.C.S. recovered in maunds per acre was not significantly different with the different treatments. All the same, highest C.C.S. was recorded with the mechanical method of weed control. Among forms of nitrogen, differences were least pronounced though Chilean nitrate gave the highest C.C.S. Among doses, the highest dose again gave best response.

TABLE I

SHOWING YIELD OF CANE AND C.C.S. IN MAUNDS PER ACRE

Treatments	Yield in mds./acre	C.C.S. in mds./acre
F_1	537.19	67.07
F_2	575.75	68.36
F_3	555.00	67.25
N_1	524.75	63.76
N_2	552.48	68.79
N_3	580.70	70.12
W_0	629.32	73.64
W_1	512.93	62.92
W_2	515.69	66.13
'F' test.	Significant for weed control measures. S.E. (mean) ±10.833 C.D.@ 5% 31.769 C.D.@ 1% 43.181	Not significant

Average sucrose and purity percentages of juice (Table II) at harvest showed little variation due to treatments, none of the responses attaining the level of significance. Comparatively higher sucrose and purity values were, however, noticeable in case of mechanical weed control.

TABLE II

SHOWING SUCROSE AND PURITY PERCENTAGES AT HARVEST

Treatments	Sucrose percent	Purity percent
F_1	16.72	89.36
F_2	16.91	88.82
F_3	16.75	88.40
N_1	16.70	87.89
N_2	16.95	88.84
N_3	16.73	89.85
W_0	16.96	89.47
W_1	16.41	88.40
W_2	17.01	88.72
'F' test.	Not significant. S.E.(mean) ±0.488	Not significant. S.E.(mean) ±1.077

Average dry weight of weeds per square foot (Table III) was significantly reduced in case of mechanical weed control, proving its value in efficiently combating weed growth in sugarcane. The hormonal weedicide Dicotox (2, 4-D ester) killed all the dicot weeds in course of two months but stimulated the growth of Makra grass (*Dactyloetenium aegyptiaca*) which was the major weed in the experimental area. It had however some depressing effect on Motha (*Cyperus rotundus*). Copper sulphate, on the other hand, had no effect on grass weeds. It affected certain broad leaved weeds due to its corrosive action, but with irrigation and availability of moisture the weeds picked up growth after overcoming the light damage caused by copper sulphate.

TABLE III

SHOWING AVERAGE DRY WEIGHT IN GMS. AND AVERAGE NUMBER OF WEEDS PER SQUARE FT. AT THE FIRST OBSERVATION AND BEFORE EARTHING UP

Treatment	Average dry weight/Sq. ft. in gms.			Average No. of weed/Sq. ft.		
	4,5 June	23 July	Increase or Decrease %	4, 5 June	23 July	Decrease %
F_1	48.33	73.98	+53.07	34.16	29.32	14.17
F_2	39.83	67.70	+69.97	31.22	27.22	12.89
F_3	46.39	73.58	+58.61	34.14	27.88	18.34
N_1	45.03	65.40	+45.24	32.11	32.00	0.35
N_2	45.11	71.63	+58.79	32.27	27.10	16.02
N_3	44.42	78.22	+76.88	35.14	25.32	27.95
W_0	37.42	32.20	—13.95	34.66	32.10	7.39
W_1	46.61	97.98	+110.21	33.88	24.10	28.87
W_2	50.53	85.07	+68.35	30.97	28.22	8.88

'F' test.	Significant for weed control measures	Significant for nitrogen doses and weed control measures
	S.E. (mean) ±4.749 C.D. at 5% 16.432 C.D. at 1% 24.892	S.E. (mean) ±0.956 C.D. at 5% 3.308 C.D. at 1% 5.102

Although there was no significant difference among nitrogen doses with regard to weed growth, higher doses were found to increase growth of weeds in general. This, however, seemed to be unaffected by forms of nitrogen. In case of weed population per square foot, although the differences between treatments were not significant, Calcium nitrate tended to be the best in reducing the population. Higher doses of nitrogen also reduced the weed number significantly. 2, 4-D treated plots also showed a significant reduction in weed number, showing thereby that heavy weed growth reduced the number of weeds in unit area. Further 2, 4-D reduced the number of all treated broad leaved weeds viz. (1) *Amaranthus viridis*, (2) *Celosia argentea*, (3) *Digera arvensis*, (4) *Heliotropium eichwaldi*, (5) *Corchorus obitorius* etc., which together constituted about 10 percent of the total weed population.

CONCLUSION

A study on the relative efficiency of different forms and doses of nitrogen in conjunction with measures of weed control revealed the following facts :

(1) All the forms are equally efficient as carriers of nitrogen for sugarcane when compared on an equal nitrogen basis. Under the experimental conditions, Chilean nitrate did slightly better than the other forms.

(2) Different doses of nitrogen viz., 40, 80 and 120 lbs. per acre have not indicated significant differences in the yield of sugarcane.

(3) The mechanical measure of weed control appears to be the best for controlling weeds in sugarcane. It not only increased the yield of sugarcane significantly, but also reduced lodging and improved cane quality.

(4) Where the major weed population is of graminaceous type, post-emergence application of 2, 4-D or copper sulphate is of little use. It was noticed that 2, 4-D instead of depressing growth allowed the grasses to grow more vigorously by reducing competition from dicotyledonous weeds. Under such conditions mechanical measures of controlling weeds are most effective.

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DISCUSSION

Dr. Arakeri thought that the dose of chemical weedicide used by Mr. Khan was rather too high. In reply to a question by Mr. Purnanand, Mr. Khan said that 2, 4-D was applied all in one dose and that a 150 maunds increase in yield was obtained with mechanical weed control. Dr Thakur wanted to know the common weeds found in the fields under experimentation and whether all of them could be controlled. Mr. Khan replied that 90 percent of weeds were monocots consisting principally of the *Digitaria* species, *Cyperus rotundus* and *Cyanodon dactylon* and 10 percent were dicots comprising *Amaranthus* and *Digeria* species. He opined that 2, 4-D was more effective on dicots whereas it stimulated monocots. Dr. Thakur remarked that when 90 percent of weeds were monocots and they were stimulated by 2, 4-D, control by this chemical could hardly be comparable with mechanical weed control Mr. Khan replied that there was no other alternative course to follow under the circumstances. In reply to a question by Dr. Rochecouste on the method of mortality assessment, the author said that the dry weight in one square foot was taken as the unit for estimation.

JUICE QUALITY

In the absence of the authors, the following paper was taken as read.

Paper

STUDIES IN THE JUICE QUALITY OF SUGARCANE STALK SECTIONS IN RELATION TO THEIR TIME OF FORMATION AND CULTURAL TREATMENT

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INTRODUCTION

The relationship between age of stalk as also the time of origin and its juice quality has been studied by many research workers all over the world. Stubbs (16), Barber (2), Rodrigues (15), Arceneaux (1), Locsin (10), Panje (12), Vasudeva Rao and Lakshmikantham (18), Ramakrishna (14) and Dillewijn (6,7) reported on juice quality of individual cane stalks in relation to their time of origin. Varahalu (17) found that it is not age alone but the sequence of seasonal conditions through which a crop passes and the duration of its stay in each period that determines its juice quality.

Sugarcane is rotated with rice in the Andhra State. Hence cane and rice fields are situated adjacent to each other resulting in some seepage and inevitable stagnation of water to varying extents in the former fields. Lakshmikantham (8) found that the general effect of swampy conditions was to hasten maturity and lower cane yields. Recent experience at Anakapalle indicated that the time of onset of water logged conditions has an important bearing on crop performance. Detailed studies were therefore undertaken to find out the effect of swampy conditions on individual canes and the different sections constituting the same with reference to their time of formation and commencement of swampy conditions. The three standard varieties Co. 419, Co. 449 and Co. 527 were under study both under normal and swampy conditions. Results of these studies are presented in this paper.

REVIEW OF LITERATURE

Detailed examination of the different parts (joints) of individual stalks was conducted by Barber (2) who suggested a system of measurements for testing the suitability of sugarcane varieties to different localities in this country. Viswanath (19) found that in a young cane, the maximum amount of total sugars is found at the basal joints and as the cane grows older, this maximum sugar content moves higher and higher till it is at the highest dead leaf joint. According to him, the nearer the maximum total sugar content is to the highest dead leaf joint, the more advanced the cane is in maturity. Ramiah and Varahalu (13) stated that "taking the cane as a whole, the concentration in it commences to increase earlier at its bottom, but taking each internode in it individually, the increase occurs earlier at its top. With advance in age, the concentration in both gets to be maximum in their central parts." Cornelison and Cooper (3) opined that each joint represents the accumulated effects of the growth factors operative at the time of formation of the particular joint. At this time the total cell capacity is established but not the final concentration of the cell contents. "As the joint ages, utilisation of sucrose is reduced, the storage space increased by reduction in volume of the protoplasm and transfer of nitrogenous matter for reuse elsewhere and sucrose is moved from the top to fill the gap."

Dillewijn (5) confirmed the findings of Ramiah and Varahalu in respect of juice concentration in the different parts of an internode and reported that there will be a standard internode in a stalk whose 'piercer brix' equals the brix of the mixed juice of the entire stalk. Lakshmikantham (9) observed significant improvement in C.C.S. % of canes from which a three budded piece from the top was removed, both in the case of Co. 419 and Co. 527.

MATERIAL AND METHODS

The three varieties chosen for the study viz., Co. 419, Co. 449 and Co. 527 were planted separately in two fields on the same day (16th February 1954). The crops received 100 lbs. N per acre as sulphate of ammonia in two equal doses on the 7th April and 31st May. One hundred primary shoots in each variety in both the fields were labelled as they came up. The plants were earthed up on the first of June. On the same day existing stalk growth in the labelled canes was marked as section one, by putting a mark with paint at the leaf scar of the 3rd leaf sheath attachment. (The leaf at the highest visible leaf joint is taken as the first one and counting downwards the third leaf has been fixed). On the first of every subsequent month till November, sections of canes that were formed during the respective months were marked in a similar manner (marking at the leaf scar denoted by the 3rd leaf sheath attachment). Thus seven sections, as detailed below, were noted on each stalk with reference to the period of their formation.

Stalk portion that grew up from planting to end of May			1
Do.	Do.	during June	2
Do.	Do.	Do. July	3
Do.	Do.	Do. August	4
Do.	Do.	Do. September	5
Do.	Do.	Do. October	6
Do.	Do.	from November till harvest	7

The period from which the commencement of growth of a section is reckoned (beginning of the months of June, July etc. for the sections formed in these respective months) is taken into consideration for fixing its age. For the first section (marked at the end of May) however, age is reckoned from the date of planting. Water was impounded in one of the fields from 5th August to 22nd November, 1954 to create 'swampiness'. The average depth of water was 10 inches. The effect of this treatment on the vegetative development as also juice quality of the different sections was studied. The crop in the second field was grown as a 'normal one' receiving irrigations at scheduled and regulated intervals (once in 15 days in the absence of rain). The 'swamp crop' was also given irrigations once in 15 days from December onwards.

Twenty canes, selected at random, formed the sample for recording vegetative characters as also sucrose content in juice. Juice analysis was done at the end of December 1954 and January 1955. At harvest time, canes were topped at the third leaf attachment.

RESULTS AND DISCUSSION

Information in respect of the vegetative characters such as length, diameter, weight and number of internodes of each section, was recorded at final harvest in January 1955, ($11\frac{1}{2}$ months age). But in the interests of brevity, particulars regarding weights of sections alone are furnished in this paper.

WEIGHT OF SECTIONS

The average weights of the sections are presented in Table I. The sections formed during June in the case of Co. 419 and Co. 449 recorded maximum weights under both the cultural treatments, while July formed sections had the maximum weight in Co. 527. There was a progressive fall in the weights of sections formed subsequently in all the varieties (except in the case of the topmost section) and treatments. The differences between the weights of sections in the various

TABLE I

AVERAGE WEIGHT (GRAMS) OF SECTIONS AS RELATED TO THEIR TIME OF FORMATION, RECORDED IN JANUARY 1955 AT FINAL HARVEST

Period of formation of section	Age of section at harvest in months	Canes grown under normal conditions			Canes grown under swamp conditions		
		Co. 419	Co. 449	Co. 527	Co. 419	Co. 449	Co. 527
Upto end of May	11½	112	78	82	138	55	78
During June	8	442	300	309	381	275	203
,, July	7	398	272	312	317	260	288
,, August	6	315	226	225	290	209	198
,, September	5	250	245	200	222	152	120
,, October	4	118	93	109	104	69	13
Novermber to harvest	3	137	92	85	111	109	18

SUMMARY OF RESULTS

Particulars	Mean weight of sections in grams							Standard error of treatment (mean)	Significant or not	Critical difference at P= 0.05
	Up to end of May	June	July	August	September	October	November to harvest			
Time of formation	90.5	318.3	307.8	243.8	198.2	84.3	92.0	9.45	Yes	29.1
Culture	Normal			Swamp	Loss in weight of swamp sections as a percentage of that of normal ones					
	209.5			164.1	21.7			0.05	Yes	15.6
Varieties	Co. 419			Co. 449	Co. 527					
	238.2			173.9	160.0			6.19	Yes	19.1

treatments, viz., times of formation, cultural treatments and varieties were statistically significant.

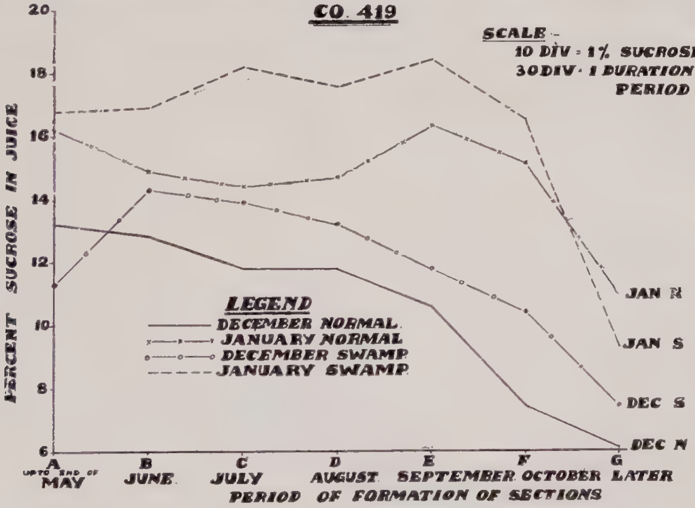
The weights of sections formed prior to water stagnation were 87.8, 90.8 and 80.9 percent of the weights of corresponding 'normal' sections as against 88.7, 82.2 and 56.4 percent in the post stagnation period in Co. 419, Co. 449 and Co. 527 respectively. The data indicated that the sections of the swamp crop were in general inferior to those from the normal one, those formed in the post stagnation period losing more weight in the case of two out of three varieties. Co. 527 was found to be least tolerant to swamp conditions recording maximum percentage loss of weight of sections.

JUICE QUALITY

Individual sections were crushed separately and brix, sucrose and purity values of juices determined in December and January. It has been the experience here that when crops subject to water logged conditions for a long period are kept on the field after it has dried up, their juices tend to deteriorate. The effect varies with varieties, and Co. 527 seemed to be more adversely effected in this respect than others as could be seen from the juice sucrose data furnished in Table II. There was perceptible deterioration in January in the sucrose content of juice of Co. 527 sections formed till July.

FIG 1

JUICE SUCROSE IN STALK SECTIONS AS RELATED TO THEIR TIME FORMATION



The time of formation, rather than age of sections seemed to influence their juice quality as in the case of the entire crop studied by Varahalu (17). The sucrose values of juices have been graphically presented in Figures 1 to 3 to bring out clearly the influence of time of formation of a section on its juice sucrose content. Maximum sucrose percentage was recorded by the sections formed in

TABLE II

SUCROSE PERCENT IN JUICE OF SECTIONS AS RELATED TO THEIR TIME OF FORMATION

Period of formation of section	Age of section at harvest in months	DECEMBER						Age of section at harvest in months	JANUARY					
		Canes grown under normal conditions			Canes grown under swamp conditions.				Canes grown under normal conditions			Canes grown under swamp conditions		
		Co. 419	Co. 449	Co. 527	Co. 419	Co. 449	Co. 527		Co. 419	Co. 449	Co. 527	Co. 419	Co. 449	Co. 527
Up to end of May	10½	13.19	13.49	10.42	11.34	13.00	12.23	11½	16.24	16.43	16.94	16.75	14.69	12.05
During June	7	12.77	13.73	11.80	14.31	14.20	13.91	8	14.86	17.38	16.88	16.88	17.35	12.83
,, July	6	11.82	13.79	11.89	13.93	14.83	14.56	7	14.37	17.57	17.14	18.16	18.28	13.81
,, August	5	11.76	14.11	11.60	13.21	14.73	14.79	6	14.68	18.04	17.42	17.64	18.36	15.52
,, September	4	10.63	12.93	10.95	11.81	14.54	14.02	5	16.42	18.92	17.97	18.47	19.73	16.25
,, October	3	7.42	10.26	8.72	10.35	13.73	14.04	4	15.18	17.81	18.02	16.59	18.31	15.16
November to harvest	2	6.12	9.83	8.00	7.35	10.95	11.03	3	10.89	14.76	13.24	9.26	14.51	11.40

SUMMARY OF RESULTS

Particulars	Mean sucrose % in Juice							Standard error of treatment (mean)	Significant or not	Critical difference at P = 0.05
	Up to end of May	June	July	August	September	October	November to harvest			
Time of formation	13.90	14.74	15.01	15.15	15.22	13.80	10.61	0.1658	Yes	0.51
Culture	Normal		Swamp		Improvement in sucrose content of swamp sections as of that of normal ones					
	13.72		14.40				5.1	0.0886	Yes	0.27
Varieties	Co. 419		C0. 449				Co. 527			
	13.30		15.22				13.66	0.1085	Yes	0.33
Months		December			January					
		12.10			16.03			0.0886	Yes	0.27

September, irrespective of the cultural treatment or variety except in one instance. Even in this case (Co. 527 normal) the September sucrose content (17.97%) was practically similar to the maximum (18.02%) registered in October.

FIG 2

JUICE SUCROSE IN STALK SECTIONS AS RELATED TO THEIR TIME OF FORMATION

CO 449

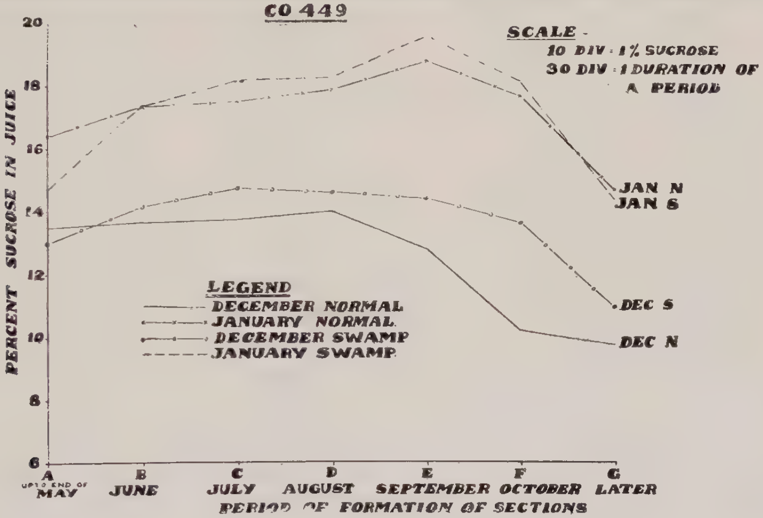
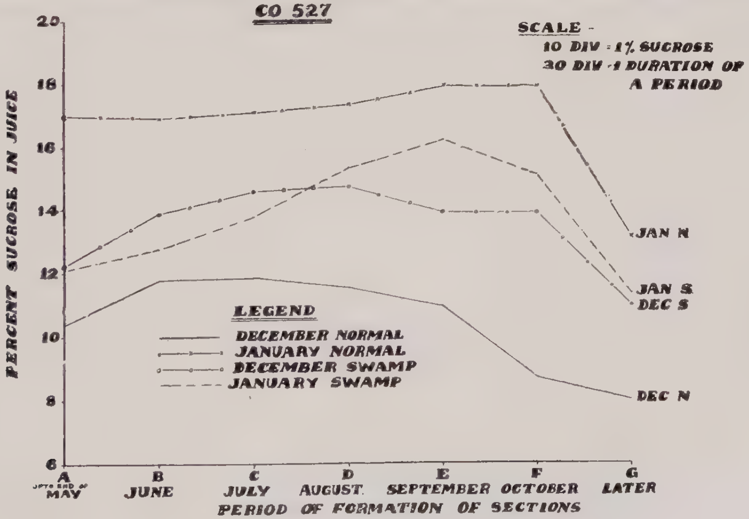


FIG 3

JUICE SUCROSE IN STALK SECTIONS AS RELATED TO THEIR TIME OF FORMATION

CO 527



The average sucrose percentages of sections formed in August (15.15%) and July (15.01%) closely followed that of September (15.22%) section. The differences in sucrose values of sections formed at different periods were statistically significant. The varietal differences, as also the differences due to cultural treatments were significant. December analysis figures indicated that water stagnation increased juice sucrose. But the improvement in juice quality as compared to the normal sections was much more in the sections formed after swampy conditions set in. The superiority in juice sucrose was maintained by these sections except in Co. 419, even in January when the crops were mature.

Against 113.0%, 97.9% and 75.9% of the sucrose values of sections formed upto end of July those that were formed later recorded 108.4%, 101.9% and 87.4% of the sucrose contents of the normal ones in Co. 419, Co. 449 and Co. 527 respectively in January.

The coefficients of purity of juices in the different sections of the 'swamp' and 'normal' crops are furnished in Table III. Maximum purity values were recorded by September sections in three out of six cases and August sections had maximum purity in two treatments ; while in one treatment (Co. 419) cane formed till end of May registered highest coefficient of purity.

That a crop subject to swamp conditions matures early but loses weight has been reported by Lakshmikantham (8). Khanna and Sen (11) observed that crops subject to water logging recorded maximum sucrose values. The results of this study indicated that the average loss in weight of the different sections of the swamp crop is much more important (21.7%) than the gain in juice sucrose (5%) due to water stagnation, provided the crops are harvested at the age of about 12 months after reaching maturity (Vide Tables I and II). As for the maximum accumulation of sucrose in individual sections, the findings from this investigation seemed to be more in accordance with the results recorded by Viswanath (19) than those observed by Ramiah and Varahalu (13). Viswanath stated that the nearer the maximum total sugar content is to the highest dead leaf joint the more advanced the cane is in maturity while according to the latter authors, with the advance in age, the concentration in the cane gets to be maximum in the central parts. It was observed that the 6th or 7th internode from the top (counting from the 3rd leaf joint) carried the highest dead leaf when mature canes (aged about 12 months) are harvested at this station. The number of internodes above the September section in this investigation, ranged between 6.3 to 9.47. So some of these sections contained the highest dead leaf joint while a few are one or two joints below it. Hence it may be inferred that the results are in general accordance with those recorded by Viswanath (19) though only juice sucrose and not total sugar, has been estimated in this study.

SUMMARY AND CONCLUSIONS

The results of a study of the stalk sections of varieties Co. 419, Co. 449 and Co. 527, raised under two sets of cultural treatment (Normal and water logged conditions) are presented in this paper.

The cane sections formed till (1) end of May, during (2) June, (3) July, (4) August, (5) September, (6) October and (7) November till harvest, were marked and studied separately.

TABLE III

JUICE PURITY IN SECTIONS AS RELATED TO THEIR TIME OF FORMATION

Period of formation of section	DECEMBER							JANUARY						
	Age of section at harvest in months	Canes grown under normal conditions			Canes grown under swamp conditions			Age of section at harvest in months	Canes grown under normal conditions			Canes grown under swamp conditions		
		Co. 419	Co. 449	Co. 527	Co. 419	Co. 449	Co. 527		Co. 419	Co. 449	Co. 527	Co. 419	Co. 449	Co. 527
Up to end of May	10½	81.37	84.57	75.94	73.59	79.76	79.67	11½	89.92	91.48	91.32	91.23	89.25	86.94
During June	7	78.34	84.28	79.94	80.66	85.34	83.24	8	86.60	91.04	90.95	91.29	91.03	87.94
,, July	6	75.22	84.55	80.23	78.39	85.43	85.14	7	84.23	92.52	90.88	93.80	92.51	87.63
,, August	5	75.77	85.56	79.13	76.62	85.39	86.61	6	85.05	93.04	92.86	90.65	93.86	90.39
,, September	4	72.02	80.71	78.77	71.02	86.19	82.33	5	88.00	97.57	93.30	91.93	91.96	88.85
,, October	3	60.47	72.25	70.26	69.62	88.87	81.86	4	83.13	86.62	92.12	89.24	95.07	86.83
November to harvest	2	58.66	70.16	64.00	54.36	76.29	76.70	3	70.90	84.53	78.53	70.74	84.07	81.66

SUMMARY OF RESULTS

Particulars	Mean purity							Standard error of treatment (mean)	Significant or not	Critical difference at P=0.05
	Up to end of May	June	July	August	September	October	November to harvest			
Time of formation	84.59	85.89	85.90	86.24	85.55	81.36	72.55	1.151	Yes	3.26
Culture	Normal 82.07			Swamp 84.24				0.615	,,	1.74
Varieties	Co. 419 73.77		Co.449 80.93	Co. 527 78.13				0.754	,,	2.13
Months		December 77.61		January 88.70				0.615	,,	1.74

The differences between the weights of sections were found to be statistically significant with reference to the time of formation. The cultural treatment (swamp conditions from August to November) lowered the weights of stalk sections significantly. June formed sections recorded the maximum weights in Co. 419 and Co. 449, while July formed ones in Co. 527 weighed highest. The sections in the swamp crop weighed less than those of normal. Swamp conditions adversely affected the weights of stalk sections formed even earlier than their commencement. But those formed after water stagnation set in, lost more weight than the ones formed earlier as compared to the corresponding normal sections. Time of formation had a significant effect on the sucrose content of stalk sections. Maximum juice sucrose values were recorded by the September formed sections irrespective of the cultural treatment or the varieties. Stalk sections in the 'swamp crop' were, in general, richer than the corresponding ones from the normal crop. The average loss in weight was found to be much more than the average gain in sucrose content of stalk sections when the crops subjected to water logged conditions for a prolonged period of about 4½ months.

ACKNOWLEDGEMENTS

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Dr. A. S. Chacravarti then presented the following paper.

Paper

APPLICATION OF PHYTOHORMONE TO SUGARCANE

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INTRODUCTION

A good deal of work has been published in recent years on the subject of phytohormones and their role in relation to various aspects of plant metabolism. Thus, stimulation in respiration by application of low concentrations of hormones like, 2, 4-dichlorophenoxyacetic acid (2, 4-D) and indole acetic acid (I.A.A.) is reported in case of *Avena* and pea stem tissues (1-4) as also increased carbon dioxide output in bean and morning glory plants and ripening fruits of several kinds (5-7). Similarly, increase in oxygen uptake has been observed in certain intact plants sprayed with 2, 4-D (8). Application of 2, 4-D or I.A.A. to aerial parts has also been associated by several workers (6, 8-13) with a marked acceleration in hydrolysis, translocation and utilisation of carbohydrate reserves. Both these hormones, as also others like indole butyric acid (I.B.A.), naphthalene acetic acid (N.A.A.) and naphthoxyacetic acid, have been found to induce accelerated starch hydrolysis in the leaves of bean and morning glory plants (10, 12, 14) and the same observation is reported in respect of the stem of intact tomato plants treated with I.A.A. (15). Accelerated hydrolysis of complex carbohydrates such as hemicelluloses has likewise been found to be induced by 2, 4-D (16). In detached fruits like banana, pear and apple, hastening of starch hydrolysis by growth regulators has been reported (3, 5, 17). Increased starch hydrolysis and accumulation of sugars in bean plants has likewise been induced by N.A.A. (18). Profound effects of hormones on the enzyme systems of plants have been recognised. Thus, enzymes diffusing from sections of bean plants treated with 2, 4-D have a higher capacity to digest starch in agar media (19). Alcohol dehydrogenase is enhanced by treatment with I.A.A. (20-22), although no *in vitro* effect on cytochrome, ascorbic acid, catechol or glycolic acid oxidases results from treatment with 2, 4-D or I.A.A. (23). The latter hormone appears to affect growth through a sulfhydryl enzyme system and to be involved in aerobic phosphate transfer (24-26). Growth stimulation by hormones has been attributed to a release of diastase from inactive to active form (27-29). Oil content of flax as also iodine number is adversely affected by hormone applications (30-32), a depression in the activity of castor bean lipase being also reported (33). In treated bean stems, a large increase has been recorded in B vitamins which are co-enzymes in intermediary carbohydrate metabolism. A definite shift in the concentration of certain vitamins in the stem and leaf tissues is also occasioned by 2, 4-D (34). Pods of bean plants sprayed with 4-chlorophenoxyacetic acid show a slower rate of vitamin C breakdown during storage (35). Nitrogen metabolism is also affected, increased protein synthesis (11, 18, 36-42), rise in amino acids and water soluble nitrogen compounds (11, 18, 36, 38) as also a mobilisation of nitrogenous constituents towards the basal parts of stem (13, 15, 38, 43) having been reported. The water content of cells increases (4) which is also paralleled by increase in cell size (44, 45). In bean plant, water content of leaf tissue is depressed while that of stem tissue rises (4). Increase in mineral content is also brought about (46). Movement of P, K, Mg, Mn, B and Cu into treated regions of stem increases rapidly, mobilisation of Fe and Al being relatively slow (46, 47). 2-methyl 4-chlorophenoxy acetic acid (M.C.P.) interferes with potassium metabolism of rape but not of oats (48). 2, 4-D treatment hastens ripening of peaches, pears and apples (5) as also of bananas (49), storage life being also improved in some cases. Application of 2, 4, 5-trichlorophenoxyacetic acid (2, 4, 5-T) hastens maturation of calimyrna figs from a normal period of 120 days to one of 60 days (50). The absorption and translocation of hormones by plants has also been studied. Thus, it has been found that although young rapidly growing leaves may absorb 2, 4-D, they may fail to translocate it to other parts of the plant (51), a more ready translocation of phenoxy compounds being noted in case of leaves of medium age as compared to younger or older ones (52). Movement of 2, 4-D from leaves apparently involves a mechanism same as or similar to that involved in the translocation of products of photosynthesis (51, 53, 54, 55). I.A.A. and phenoxy compounds are apparently absorbed by most leaf surfaces and this does not appear to be related to the presence of stomatal openings. Better absorption is shown by young vigorously growing parts (55). Dicots absorb growth regulators more readily than monocots (56). Bean plants absorb sufficient 2, 4-D in 4-6 hours to bring about maximum response (57). Young and succulent plants often show marked growth responses (within 30-60 minutes) to phenoxy types and I.A.A. is quickly absorbed by succulent tissues of various plants (51, 52). Light increases absorption of 2, 4-D (54), higher temperatures also favouring the same (58, 59). Wetting agents and hygroscopic substances that dissolve the growth regulator markedly enhance its activity (60-64). Admixture of carbowax with a solution of 2, 4-D (salt form) produces a relatively rapid rate of absorption over an extended length of time (61). Dispersing agents and soapless washing powders containing lauryl sulphate greatly augment activity of 2, 4-D to an extent that cannot be explained on the basis of reduction in surface tension alone. Both absorption and translocation are enhanced in the presence of surface active agents (65). Absorbed by leaves, 2, 4-D is translocated mainly in the living cells of phloem and a few micrograms of the chemical placed on the leaf can, under certain conditions, be translocated to the stem where it is moved in both upward and downward directions (62).

The question of phytohormone application to sugarcane for raising its sugar content has recently engaged the attention of workers in different countries. Beauchamp (66-68), reported gains in sucrose content of cane to the extent of almost 1.5 unit resulting from foliar sprays of very weak solutions of 2, 4-D (sodium salt), the effect being most pronounced during the second ten day period following treatment whereafter there was a tendency to slow decline. However, the effect was of a substantial magnitude even after a period of 45 days. The hormone also proved effective when applied to the foliage as dust or to the soil like a fertiliser. Subsequent workers, however, failed to get consistent positive results. Thus, De La Vega (69) found increases in sugar content in 50% of the cases examined and decreases in the rest. Haskow (70, 71) also observed no response in sugar content or C.C.S. per acre to 2, 4-D sprays at concentrations of 5 and 30 p.p.m. Negative results were likewise reported from Australia (72). Loustalot, Cruzado and Muzik (73) in Puerto Rico, using 0.2% isopropyl ester of 2, 4-D, observed no significant effect on juice quality. In India, on the other hand, Mathur (74) found a rise in sucrose percent juice to the extent of 0.7-0.8 unit 2-5 days after spraying at a concentration of 0.2% but the effect was not perceptible at later stages. Similarly, Lakshmikantham and Prasadrao (75) reported a beneficial effect on the sucrose content of juice resulting from spraying at concentrations of 0.25% and 0.50%, a dose of 50 p.p.m. proving ineffective. Neither these workers nor Mathur (loc. cit), however, indicated the statistical significance or otherwise of the results obtained. Notwithstanding the above divergence of opinion with regard to the effect of 2, 4-D on sucrose content of cane, it seems to be accepted that the growth of sugarcane is not affected adversely even at the early stages of growth by fairly high concentrations of the hormone (76, 77).

In the present paper, the results of studies undertaken by the authors in respect of the problem have been described, the work consisting of (i) a series of small scale field trials and (ii) a series of large scale field trials involving milling tests at the factory.

EXPERIMENTAL PROCEDURE AND RESULTS

(*a*) *Small scale field trials* :

(i) *Variety B. O.* 21 : The trial with this variety was laid out under 5×5 Latin square design, the treatments involved being 0, 0.1%, 0.4%, 0.7% and 1.0% sprays of 2, 4-D (sodium salt) at 60 gallons per acre. Gross plot size was 60.5′×24′ and net plot size 60.5′×12′. Spraying was done in the month of December when the crop was of 14 months age. Soil was calcareous sandy loam and manuring consisted of 60 lbs. N×75 lbs. P_2O_5 per acre over a basal dressing of green manure. The crop had received 4 irrigations in hot weather amounting to a total of 12 acre inches. Samples were drawn 1, 2, 3, 5, 8, 17, 22 and 23 days after spraying, each sample consisting of 10 clumps selected at random. The entire sample was crushed in a bullock driven crusher and the juice analysed for brix, polarisation and purity.

(ii) *Variety B.O.* 3 : This trial was laid out under 3×2 randomised blocks, the treatment being 0, 30 and 70 p.p.m. 2, 4-D (sodium salt) at 60 gallons per acre as spray. Soil, manuring and plot sizes were the same as in the previous trial. Age of crop was 11 months, spraying being done in January. The crop was an unirrigated one. Samples were drawn 2 and 8 days after spraying, seven samples of ten random clumps each being taken from every plot on both days. All were analysed for brix, polarisation and purity.

(iii) *Variety B.O.* 28 : The layout consisted of 3×3 randomised blocks, plot size being 9′×9′. Treatments were 0, 50 p.p.m. 2, 4-D (sodium salt) and 50 p.p.m. 2, 4-D (amine salt) sprayed in January at 60 gallons per acre. Sampling was done 2 and 17 days after spraying, half the crop in each plot being harvested on each occasion. Age of crop was 15 months. Soil, manuring and irrigation were the same as in case of B.O. 21. Besides brix, polorisation and purity, analyses included reducing sugars as well.

The results obtained in all these trials were, however, statistically non-significant, the data having been omitted for brevity. This might mean that 2, 4-D had no effect on the sucrose content of cane but the following possibilities could not also be ruled out :—

(1) The trials might need a very much larger number of replications. In fact, the standard errors in these trials proved to be quite high for all criteria.

(2) Procedure of cane sampling for juice analysis might not be adequate to enable detection of small differences, the error involved in sampling 10 random clumps per plot being ±0.5 in pol. percent juice.

(3) Fluctuation in pressure due to variations in the mill setting of the bullock crusher used might occasion errors in the pol. percent of the extracted juice.

(4) Even if there was a difference in pol. percent cane, the same might

not be detected in the juice extracted by a bullock or hand mill in as much as these afford the richest fraction of juice corresponding to a very partial extraction. It was possible that in this fraction of the juice, the overall effect on the sugar content of cane might not be perceptibly reflected.

(5) Analysis of first expressed juice can only give a very rough idea of the sugar in cane. In the present case, the effect of treatment on the quantity of juice and fibre content being an unknown factor, juice analyses might not reveal the true picture.

(6) In small scale field trials involving treated and control plots in close proximity, the control plot might get treated to some extent as a result of drift in the spray and considering the minute amounts in which hormones produce their effects, this itself could level down differences.

A cumulation of errors arising out of the above sources may conceivably mask the effects of 2, 4-D (if any) and the inconsistent or negative findings of previous workers, which all appear to be based on small scale field trials involving laboratory analyses of hand mill juice obtained from representative samples of cane, must therefore be considered with this reservation. In order to examine this important question on a sounder basis, it was accordingly decided to undertake work on a large scale involving large quantities of cane material and milling tests (about ½ hour's crushing) under actual manufacturing conditions. In the succeeding section, this work has been described.

(*b*) *Large scale trials at sugar factories.*

The trials were laid out at three places, viz., Nawtan and Dumri Farms of M.P. Sugar Mills Ltd., Majhaulia (District Champaran) and Chakthat in the reserved area of New India Sugar Mills Ltd., Hassanpur (District Darbhanga). At each place, a large block of 8-10 acres under the same variety of sugarcane was taken and divided into plots of about an acre in size. Alternate plots were used for treatment and control, leaving 15 ft. buffer on either side. The two plots were harvested at the same time on the desired date and the material in each was subjected to milling tests at the factory. The difference in estimated recovery provided a reliable measure of the effect of treatment, sampling and other errors being practically eliminated on account of the large quantity of cane crushed as also in view of the fact that the assessment was carried out under actual manufacturing conditions. The treatment used was a spray of a 50 p.p.m. solution of Na salt of 2, 4-D (with a wetting agent), the varieties being B.O. 10 at Nawtan, B.O. 17 at Dumri and B.O. 11 at Chakthat. Spraying was done in the end of January at the first two places and in mid-February at the last named site. Plots were harvested 2 days after spraying at Chakthat, 2 and 27 days after spraying at Nawtan and 2, 28 and 31 days after the treatment at Dumri. The soil was calcareous sandy loam at all places, manuring being one of 60 lbs. N + 75 lbs. P_2O_5 per acre over a basal dressing of green manure. Age of crop was 15 months at Nawtan and Dumri and 12 months at Chakthat. At the two last named places, the crop was unirrigated while at Nawtan, it had received 12 acre inches in the hot

TABLE I

SHOWING MILLING TEST DATA IN HORMONE SPRAYING TRIALS

Particulars	I Majhaulia factory (Nawtan Farm): Variety B.O. 10 Spray : 28th Jan. Harvest:30th Jan. (Interval 2 days)		II Majhaulia factory (Nawtan Farm): Variety B.O. 10 Spray:30th Jan. Harvest:26th Feb. (Interval 27 days)		III Majhaulia factory (Dumri Farm): Variety B.O. 17 Spray:29th Jan. Harvest:31st Jan. (Interval 2 days)		IV Majhaulia factory (Dumri Farm): Variety B.O. 17 Spray:31st Jan. Harvest:28th Feb. (Interval 28 days)		V Majhaulia factory (Dumri Farm): Variety B.O. 17 Spray:31st Jan. Harvest:3rd Mar. (Interval 31 days)		VI Hassanpur factory (Chakthat Farm). Variety B.O. 11. Spray: 17th Feb. Harvest: 19th Feb. (Interval 2 days)	
	Treated	Control	Treated	Control	Treated	Control	Treated	Control	Treated	Control	Treated	Control
Sugar % cane	14.08	13.75	14.39	13.85	14.12	13.52	13.62	13.28	14.36	13.60	14.07	13.43
Fibre % cane	16.78	17.16	18.05	18.85	16.62	17.20	18.85	19.22	19.55	20.45	17.62	14.19
Brix crusher juice*	20.99	20.99	22.33	22.33	20.66	20.96	21.52	21.92	22.19	22.09	20.56	20.91
Pol % ,, ,,	19.88	19.54	20.85	20.73	18.38	18.66	18.92	19.36	19.39	19.46	18.35	18.21
Purity % crusher juice	94.7	93.1	93.8	92.8	89.0	89.0	88.0	88.4	87.4	88.0	89.3	87.1
Purity % mixed juice	89.5	88.6	88.8	87.2	85.8	84.3	83.3	82.5	84.5	83.7	87.5	85.1
Pol % bagasse	3.20	3.10	2.30	2.40	3.00	3.00	2.30	2.40	2.40	2.50	3.2	3.2
Mill extraction	93.45	93.15	94.00	93.65	93.82	93.60	93.48	93.40	93.45	93.05	90.98	92.86
Estimated recovery	11.88	11.55	12.15	11.55	11.80	11.25	11.40	11.03	12.00	11.20	11.74	11.10
Increase in estimated recovery	0.33	—	0.60	—	0.55	—	0.37	—	0.80	—	0.64	—

*In test No. VI, the figures relate to primary juice and not crusher juice.

weather followed by 3 acre inches in the end of January, a few days before the spray treatment.

The results of milling tests are presented in Table I. It will be seen that with variety B.O. 10 at Nawtan Farm, sugar percent cane and estimated recovery 2 days after spraying are higher than in control by 0.33 unit, the purity of mixed juice being 0.9 unit higher. Results are still better after 27 days, with sugar in cane and estimated recovery exceeding control by 0.54 and 0.60 unit respectively and a higher mixed juice purity to the extent of 1.6 unit. Similarly with B.O. 17 at Dumri Farm, there is an improvement in estimated recovery by 0.55, 0.37 and 0.80 unit respectively, 2, 28 and 31 days after spraying. Differences in sugar percent cane are of the same order. Mixed juice purity is higher in sprayed material to the extent of 1.5, 0.7 and 0.7 unit on the three respective dates. In the test with B.O. 11 at Chakthat, the milling trial was done at one stage only, viz., 2 days after spraying, the improvement in sugar percent cane and estimated recovery amounting to 0.64 unit, that in mixed juice purity being as much as 2.4 units. With the exception of this last named test, fibre contents were substantially lower in the treated lots. This appear to indicate that the hormone tends to increase the quantity of juice in cane. The figures for brix, pol. and purity of crusher juice, on the other hand, do not show any systematic trends and in some cases, the values are somewhat lower in case of treated material.

DISCUSSION

It appears from the above that although the small scale field trials indicate no significant response to 2, 4-D application, considerable response is brought out in the milling tests. The later data were analysed statistically and the increases in sugar percent cane, estimated recovery and mixed juice purity came out highly significant. There was a decrease in fibre content in all cases except in the test with B.O. 11 which registered an increase and the results are accordingly non-significant (vide Table II). The unsystematic trend manifested by the figures for

TABLE II

SHOWING STATISTICAL SIGNIFICANCE IN RESPECT OF DIFFERENT CRITERIA AS AFFECTED BY THE TREATMENT

Characters	Mean increase over control	t	Conclusion
Sugar % cane	0.54 ± 0.07	7.68	Highly significant.
Fibre % cane	0.07 ± 0.681	0.098	Non-significant.
Mixed juice purity	1.32 ± 0.270	4.88	Highly significant.
Estimated recovery	0.55 ± 0.072	7.66	Highly significant.

crusher juice would appear to support what has been said earlier as to the unreliability of first expressed juice as an accurate guide to sugar content of cane, be it juice expressed by the factory crusher or by a bullock or hand mill. It may be pointed out in this connection that with one exception, the milling extraction in the treated lot of cane was of the same order as or higher than that in control and this would rule out the possibility of the control recording a lower mixed juice purity due to a more thorough extraction. Considering all these facts, it can be concluded that a foliar spray of 50 p.p.m. solution of 2, 4-D (sodium salt) raises sugar in cane and recovery by 0.33-0.80 unit, the average improvement being 0.55 unit.

The following points are noteworthy in this connection, viz., that (*i*) the treatment is effective as early as 2 days after spraying, (*ii*) it remains unimpaired even after a lapse of 31 days, (*iii*) it produced a response in three different varieties, (*iv*) it is effective in two different districts fairly remote from each other, (*v*) it has an effect on both irrigated and unirrigated cane, (*vi*) it is effective irrespective of whether the crop is an autumn or spring planted one, (*vii*) response is manifested by an early variety sprayed quite late in the season (third week of February) when it had reached or was not much behind peak maturity stage, (*viii*) this response at or near the peak maturity stage is marked in other cases as well, considering the high purities of mixed juice recorded under controls 2 days after the spraying operation and (*ix*) the costs involved are insignificant and the method thus holds out considerable promise for the sugar industry.

SUMMARY

In a series of large scale trials involving milling tests at the factory, it has been found that foliar spraying of sugarcane with a 50 p.p.m. solution of 2, 4-D (sodium salt) raises sugar content and recovery by 0.33-0.80 unit, the effect being perceptible as early as 2 days after spraying and found unimpaired even after a lapse of 31 days. The tests included three varieties of cane (early and medium early ripeners), irrigated and unirrigated materials, autumn and spring planted crop, treatment in two districts fairly remote from each other as also at two different stages in the season (last week of January and third week of February), responses being observed in all cases. In view of the insignificant costs involved, the method holds out considerable promise for the industry.

ACKNOWLEDGEMENT

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DISCUSSION

Dr. Tandon remarked that in U.P. a beneficial effect of 2, 4-D on sucrose content had been observed for the first week or so after which there appeared to be a decline. Mr. Govitrikar said that results in Bombay had been inconclusive. Dr. Evans relating his experience in British Guiana said that the results were now significant and he still kept an open mind about the problem. Dr. Chacravarti in reply pointed out the various sources of error involved in small scale trials and stressed the need for conducting large scale experiments under actual manufacturing conditions so as to finally settle the issue. This was considered particularly important in the light of the consistently positive results obtained by the author in trials of this nature in contrast to non-significant results obtained by him in small scale experiments.

In the absence of the authors the following paper was taken as read.

Paper

THE SUCROSE CONTENT OF SUGARCANE AS INFLUENCED BY FERTILIZERS

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INTRODUCTION

Fertilizers play an important part in increasing sugar production mainly because of their influence on cane tonnage. Most cane growers use fertilizers regularly to maintain or gain further increases in cane yields per acre. This primary importance of nitrogen fertilizers in maintaining cane tonnage has been well recognized by the cane growers of the world. The use of phosphate and potash fertilizers for obtaining increases in cane tonnage also have proved important in many sugarcane growing areas. Even the use of lime and other minor element fertilizer material has been found to be valuable for increasing cane tonnage in certain specific cases. However, no clear picture exists of the influence of these same fertilizer materials on the sucrose content of sugarcane.

Many growers, although recognizing the beneficial effect of nitrogen fertilizers on cane tonnage, feel that high nitrogen rates are detrimental to the sucrose content of the sugarcane. Also, many growers contend that the use of potash fertilizers produces "sweeter" cane. The data in the literature related to fertilizers and sucrose concentrations are not plentiful and rather conflicting.

It is the purpose of this paper to present and interpret the data on the influence of fertilizers on sucrose concentrations in sugarcane for Puerto Rico as determined by over 12 years of fertilizer research conducted by the Agricultural Experiment Station of the University of Puerto Rico. Also presented is the influence that the fertilizers exert on the components of the available sucrose percent cane i.e., polarization, brix, and percentage of extraction. An attempt is also made to show what portion of the variation in the sucrose content of sugarcane and its components should be credited to fertility influences and what portion to such factors as variety, soil, and climate.

PROCEDURE

The data used for determining the influences of fertilizers on the sucrose content of sugarcane were obtained from sugarcane-fertilizer field experiments conducted by the Agronomy and Horticulture Department of the University of Puerto Rico. In all, 112 field experiments were utilized, 94 for major element fertilizers (N-P-K) and 18 for minor element fertilizers. The experiments were laid out using split-plot, simple randomized-block, and triple lattice designs. The majority of the experiments were replicated nine times ; the minimum number used was six replications. In all experiments with major fertilizer elements (N-P-K), whenever the rate of application of one element was varied, the other two elements were supplied at optimum rates. For nitrogen, the average increments used were 0, 125 and 250 pounds of N per acre ; the amounts of phosphorus and potassium were 0, 150 and 300 pounds per acre of P_2O_5 and K_2O respectively. In the minor element experiments, optimum amounts of mixed fertilizers were supplied to all treatments (usually 250 pounds of N and 300 pounds of P_2O_5 and K_2O per acre respectively). All fertilizer was added in one application, just before planting for plant canes and a few weeks after cutting for ratoons. The experiments included 12 cane varieties and 12 soil types covering the leading commercial sugarcane varieties and major cane growing areas in the Island.

The cane was cut as in commercial practice. Ten whole stalks of cane minus the tops were taken at random from each plot at time of cutting. These canes were tagged as to origin and were later ground in the hydraulic mill of the Agricultural Experiment Station at Rio Piedras for determination of the sucrose content. All cane samples were milled not later than 24 hours after cutting.

A hydraulic Squier mill was used which had two rollers, each one of which measured 12 by 16 inches. These rollers averaged 6.4 revolutions per minute, using a 10-horse-power Westinghouse electric motor (3). The rollers exerted a pressure of 29 tons per square inch for the extraction of the juice from the cane passing through them. Each cane sample was milled once and the bagasse also passed through once.

Available 96° sugar in the cane was calculated by using the following formula :

$$\text{Available } 96^\circ \text{ sucrose percent cane} = \frac{(0.380329 \times \text{polarization} - 0.41667 \text{ Brix})\ (\text{percent extraction})}{\text{Specific gravity } 20^\circ/20^\circ}$$

The term "polarization" as used herein refers to the value determined by direct polarization of the normal weight solution in a polariscope.

"Brix " or "degrees Brix" as used herein is defined as the percentage of solids dissolved in the juice as calculated from the index of refraction of the juice.

The term "percent extraction" or "extraction" refers to the percentage of undiluted cane juice extracted from the cane sample by passing it through the hydraulic mill once and the bagasse once. The weight of the juice mentioned above divided by the weight of the cane sample milled and the quotient multiplied by 100 gives the percent-extraction. This term is not the same, but is comparable to the term "mill extraction" used in the factory. "Purity" is defined as the value obtained by dividing the sucrose in the juice by the degrees Brix and multiplying the quotient by 100.

EFFECTS OF MAJOR ELEMENT FERTILIZERS

NITROGEN

In Puerto Rico, nitrogen is responsible for more increases in cane tonnage than any other fertilizer element used (4). The data from 94 field experiments covering the leading sugarcane varieties and producing areas were utilized in determining the influence of nitrogen application on sucrose percent cane. The results are presented in Figure 1, expressed in relative yield of cane tonnage and sucrose percent cane. This relative yield represents the percent increase in either tons of cane or sucrose of treatments with nitrogen fertilizers when compared to the no-nitrogen treatment which is used as a base of 100. The graph shows a definite linear relationship between relative yield of tons of cane and relative yield of sucrose percent cane. The regression equation obtained was $Y=88.18+0.0892X$, where Y is the relative yield of sucrose percent cane and X is the relative yield of tons of cane per acre. The regression of relative yield of sucrose percent cane on relative yield of tons of cane per acre was highly significant at the 1 percent level.

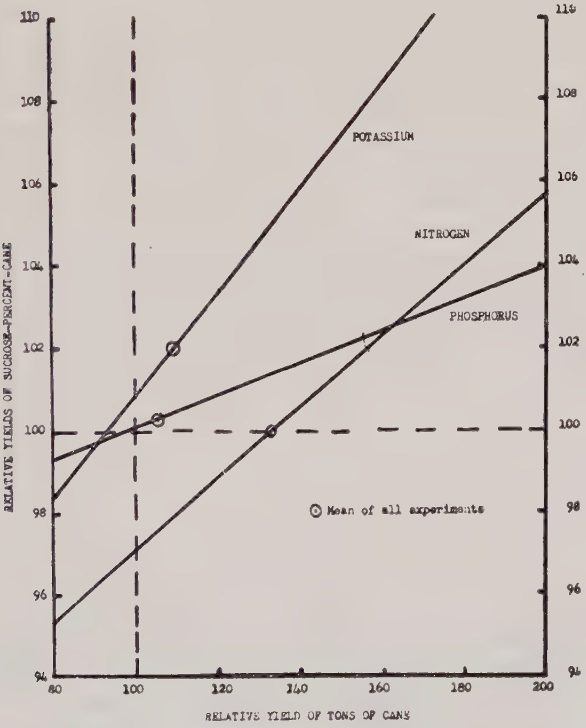

Fig. 1—Relationship between the relative yield of cane and the relative yield of sucrose percent cane as influenced by nitrogen, phosphorus, and potassium fertilizers.

The means of all the values where nitrogen was used were $Y=100.02$, $X=132.68$. In other words, nitrogen fertilizers gave an average relative yield for applications in all experiments amounting to 132.68, or 33 percent more tons of cane per acre over no-nitrogen applications, while the average relative yield of sucrose percent cane was 100.02 or no increase compared to the no-nitrogen application value of 100. From the regression equation we see that the sign is plus, and that cane tonnage and sucrose increased directly. However, from a practical standpoint, we find that nitrogen applications which produce relative cane tonnage yields below the 132 average met with no positive values (above 100) for relative yield of sucrose percent cane.

The harmful effects of heavy doses and late application of nitrogen to cane cannot be denied. Das and Cornelison in Hawaii (2) showed clearly that heavy dosages of nitrogen (645 pounds N per acre) caused lodging of the cane, more numerous daughter stalks and other suckers, higher number of dead or dying cane tops, heavier weight of cane tops, no increase in yield of millable canes over moderate nitrogen application, and poorer juice quality due to more water in the cane plant and that less sucrose is actually stored by the plant. They found that their medium nitrogen treatment (266 pounds N per acre) showed none of these adverse effects. The maximum nitrogen used in the experiments in Puerto Rico was 300 pounds of N per acre with an average of 250 pounds of N per acre. It is of course plausible to expect a decrease in both tonnage and sucrose with too heavy applications of nitrogen. For Puerto Rico, it appears that the use of up to 300 pounds of N per acre for sugar cane is not harmful in general either to sucrose percent cane or cane tonnage.

The source of nitrogen used for sugarcane had no influence on the sucrose content of the cane in experiments conducted at Rio Piedras. In Table I, the data show no significant difference regardless of nitrogen sources or the manner of application. Data given in a previous publication (5) also revealed no significant influence on yield of cane attributable to nitrogen source. Similar work in Hawaii (1) failed to reveal any difference in the sucrose yields of canes fertilized with various nitrogen carriers, namely, nitrate of soda, ammonium sulphate, potassium nitrate, calcium nitrate, urea, Calurea, Uramon and ammonium nitrate.

PHOSPHORUS

Phosphate fertilizer application showed some influence on the sucrose content of the sugarcane. The relationship obtained was positive in that sucrose concentrations increased as cane tonnage increased. The coefficient of correlation for the regression of relative yield of sucrose percent cane on the relative yield of cane tonnage was not significant at the 5 percent level. The estimation equation obtained was $Y=96.29+0.0385\ X$, where Y is the relative yield of sucrose percent cane and X is the relative yield of tons of cane per acre. The equation is shown in Figure 1.

TABLE I

INFLUENCE OF DIFFERENT NITROGEN SOURCES ON SUCROSE PERCENT CANE FOR P.O.J. 2878 AT RIO PIEDRAS.

Treatment				
Nitrogen carrier	Fertilizer per acre			Sucrose percent cane*
	N Pounds	P_2O_5 Pounds	K_2O Pounds	
None	0	50	50	12.18
Ammonium sulphate	206	50	50	12.20
Ammonium nitrate, 1 application	206	50	50	12.18
Ammonium nitrate, 2 applications	206	50	50	12.07
Uramon	206	50	50	12.33
Significant difference needed between treatments at the :				
5-percent level				0.57
1-percent level				0.75

*Average of a plant cane and two ratoons.

The average relative yield of tons of cane per acre for the use of phosphate fertilizers in all experiments was 105.35 or an increase of 5.35 percent in cane tonnage attributable to phosphate fertilizers. The average relative yield of sucrose where phosphates were applied was 100.34 which indicated no apparent change in the sucrose percent cane. In only 16 observations out of the 198 used for the phosphorus studies were the relative yields of tons of cane per acre 125 or above. The phosphorus needed for sugarcane to perform its normal physiological role in sucrose formation and accumulation seemed to be adequately supplied by the majority of the sugarcane soils of Puerto Rico and only in cases of extreme phosphate deficiencies could phosphate applications prove of any value for cane tonnage and sucrose.

POTASSIUM

The application of potash fertilizers influenced cane tonnage and sucrose content significantly. As shown in Figure 1, increases in the relative yield of cane per acre due to potash fertilizers have increases in the relative yield of sucrose percent cane. The coefficient of correlation obtained was significant at the 1 percent level. The estimation equation was $Y = 88.37 + 0.1251 X$, where Y is the relative yield of sucrose percent cane and X is the relative yield of tons of cane per acre. The general average of all experiments for potash applications was 108.78 for relative yield of tons of cane and 101.98 for relative yield of sucrose percent cane.

The slope of the line for the potassium equation was the steepest for all of the major fertilizers elements (N-P-K). It was 1.4 times steeper than nitrogen and 3.8 times steeper than that of phosphorus. In other words, an increase of one unit in relative yield of cane tonnage for potash application would give 1.4 times more increase in relative yields of sucrose than for nitrogen and 3.8 times greater than for phosphate applications.

In those cases where cane tonnage yield increases from potash applications were about 10 percent or less, the sucrose concentrations were not as consistently influenced, and they fluctuated between positive and negative responses. However, where cane tonnage yields increased more than 10 percent due to potash applications, the sucrose concentrations increased accordingly in response to potash applications. As an example, in a severely potash deficient soil, a Via silty clay near Humacao, the use of potash on a second ratoon crop raised yields from 23 tons of cane per acre (no potash added) to 36 tons per acre (300 pounds K_2O per acre added) giving a relative cane tonnage yield of 136 : sucrose percent cane was raised from 10.76 to 12.54 percent giving a relative yield of sucrose of 116.

It appears, therefore, that the application of potash fertilizer to sugarcane will appreciably increase the sucrose content of the cane if it also increases appreciably the cane tonnage at the same time.

EFFECTS OF MINOR ELEMENT FERTILIZERS

The use of minor element fertilizers on sugarcane has produced no general significant increases in the sucrose content of cane and cane tonnage in Puerto Rico. The average values from all minor element experiments showed no relative yield increases in either cane tonnage or sucrose due to minor element fertilizer applications in general.

Calcium applied as lime ($CaCO_3$) produced 6 negative responses in relative yield of sucrose content cane (values less than 100) and only 2 positive responses (values above 100). Magnesium gave 10 negative and 9 positive responses in sucrose. Copper showed 3 negative and 6 positive responses, while zinc had 7 negative and 4 positive. Boron shared equally with 7 positive and 7 negative relative yield responses in sucrose percent cane, and sulphur 3 negative in increasing sucrose concentrations.

There is no evidence in the literature of any appreciable increases in sucrose content of sugarcane with the use of minor element fertilizers. Nutrient culture work, in which a minor element was entirely omitted from the medium, provided some evidence of the need of certain minor elements for normal sucrose production. Most of the experimental soils tested in Puerto Rico, however, have sufficient supply of the needed minor elements and no appreciable responses are obtained in yield or sucrose content.

THE INFLUENCE OF MAJOR ELEMENT FERTILIZERS ON THE COMPONENTS OF AVAILABLE SUCROSE PERCENT CANE

Aside from the gross effect of the fertilizer on sucrose percent cane, the influence of the fertilizer on the factors upon which the sucrose percent cane depends, such as polarization, Brix, or percentage of extraction, also should be considered. Therefore, the data utilized in determining the influence of fertilizers on sucrose was re-evaluated for the influence of the fertilizer application on the components of available sucrose percent cane.

It is to be remembered that the results presented here are based on specific experiments wherein various fertilizer treatments had significant influence on the yield of available sucrose percent cane. Those experiments in which no very significant effect on sucrose percent cane was evidenced were not utilized in this study as it was reasoned that, if the total product, available sucrose percent cane, remained uninfluenced by the fertilizer treatment, it was very improbable that its various components could have been significantly influenced, even though in opposite ways. Therefore, the results should not be interpreted to mean that the mere use of a particular fertilizer element will produce the effect found here. As has been shown in the sections just presented, fertilizer influences were only significantly felt on sucrose when yield of cane tonnage was appreciably increased by the fertilizer. And only when fertilizer significantly influenced sucrose content were these effects described herein obtained.

NITROGEN

Where the sucrose percent cane was increased by nitrogen applications, there was also increase in polarization, Brix, purity, and percent extraction (Table II. The average increase in polarization and Brix was highly significant to the first increment of nitrogen application to the soil (125 pounds of N per acre) over the no-nitrogen treatment. The use of 250 pounds of N per acre instead of 125, however, did not give any appreciable increase (Table II) although cane yields were significantly increased up to the 250 pounds N per acre level.

TABLE II

THE INFLUENCE OF FERTILIZERS ON AVAILABLE SUGAR COMPONENTS[1].

Treatment No.	Fertilizer treatment per acre (Pounds)			Available 96° sugar in juice %	Available 96° Sugar in cane %	Polarization	Brix	Extraction %	Purity	Relative cane tonnage yields %
	N	P_2O_5	K_2O							
				Nitrogen[2]						
1	0	300	300	16.29**	11.71**	68.8**	18.9**	71.4**	8.65*	100**
2	125	300	300	17.56	12.68	73.7	19.8	72.2	8.84	164**
3	250	300	300	17.66	12.75	74.1	20.0	72.4	8.80	197

					Phosphorus[3]					
4	250	0	300	15.71*	11.41*	67.8	19.1	72.4	8.20*	100**
6	250	150	300	16.39	12.03	69.8	19.4	73.3	8.44	124
5	250	300	300	16.40	11.93	70.4	19.8	72.7	8.27	127
					Potassium[4]					
7	250	300	0	15.09**	11.17**	68.7**	19.7**	69.9	8.13**	100**
8	250	300	150	16.77	11.67	71.2*	20.0	69.6	8.38	113
9	250	300	300	16.98	11.87	72.7	20.2	69.9	8.39	116

[1] The asteriks used in the table indicate that the value obtained for treatment was significantly lower than the value for the treatment which follows.* indicates significant decrease at the 5 percent level,** indicates significant decrease at the 1 percent level.

[2] Average of 10 experiments.

[3] Average of 5 experiments.

[4] Average of 8 experiments.

PHOSPHORUS

The phosphorus deficient cane showed significantly lower values in available sugar in juice and cane, purity, and relative yields (Table II). Variations in phosphorus applications did not significantly influence polarization, Brix, or extraction.

POTASSIUM

Significantly lower values were obtained for all factors except percent extraction when potash fertilizers were not used (Table II). Polarization values were affected strongly and gave significant increases at all fertilizer levels. Percent extraction showed a smaller variation for different potassium levels than it did for nitrogen or phosphorus.

DISCUSSION

The data so far reveal that fertilizers do influence the sugar content of cane and its component factors. However, it would not be fair to leave the impression that fertilizer alone exerts a powerful influence on sucrose content. Such factors as weather, variety, and soil should be considered, for they also exert strong influences on sucrose content. At times the influence of weather, soil, or variety may mask the influence of fertilizers on sucrose content. Examples of the influence of fertilizer, weather, soil, and variety on sugar and components are given in Table III. The data were taken from field experiments, and so compiled that only the stated factor was the known variable and all other experimental conditions were kept as constant as possible. One can readily see that variations as great as or greater in magnitude than with fertilizers were obtained with such factors as varieties, soil, and weather. Therefore, it is important that all data concerning the influence of fertilizers on sucrose and its components be evaluated carefully to insure that such factors as variety, soil, and weather are not responsible for the influence found or cited.

TABLE III

THE INFLUENCE OF FERTILIZERS, VARIETIES, WEATHER AND SOIL ON THE COMPONENTS OF AVAILABLE SUGAR AND CANE YIELDS

Subject	Available 96° sugar in juice %	Available 96° Sugar cane %	Polarization	Brix	Extraction %	Purity	Cane yields per acre Tons
		Fertilizer[1]					
0-K_2O	15.12	10.31	67.6	20.3	68.2	74.48	50
150 lb. K_2O	16.53	10.91	71.7	20.7	66.0	79.86	55
300 lb. K_2O	16.60	11.02	72.7	21.1	66.4	78.67	53
		Weather[2]					
Plant cane	16.60	11.02	72.7	21.1	66.4	78.67	53
Third ratoon	16.44	11.64	70.2	19.7	69.0	83.45	54
Fourth ratoon	17.93	12.41	76.2	20.7	69.2	86.45	53
		Varieties[3]					
M. 28	16.95	12.22	71.2	19.7	72.1	86.04	34
P.O.J. 2878	15.24	10.96	65.7	18.9	71.9	80.63	42
P.R. 902	17.17	12.07	72.0	19.8	70.3	86.72	62
		Soil and Weather[4]					
Coto clay	15.24	10.96	65.7	18.9	71.9	80.63	42
Coloso silty clay	17.93	12.41	76.2	20.7	69.2	86.62	53
Fraternidad clay	14.50	10.47	67.8	19.7	72.2	73.60	33
Via silty clay	17.44	12.26	73.6	20.1	70.3	86.77	41

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1. Variety P. O. J. 2878, second ratoon, at Arecibo ; all treatments received 250 pounds N, and 300 pounds P_2O_5 and K_2O per acre.
2. Variety P. O. J. 2878, at Arecibo ; all treatments received 250 pounds N and 300 pounds P_2O_5 and K_2O per acre.
3. Third ratoon, at the Isabela Substation, all varieties received 250 pounds N and 300 pounds P_2O_5 and K_2O, respectively, per acre.
4. Variety P.O.J. 2878, all soils received 250 pounds N and 300 pounds P_2O_5 and K_2O per acre.

SUMMARY

The results of 112 field experiments with sugarcane conducted by the Agricultural Experiment Station of the University of Puerto Rico covering a wide range of varieties and soils of Puerto Rico revealed the following :

1. Nitrogen produced an increase in sucrose content with increased yields. When the relative yield of sucrose percent cane is plotted against the relative yield of tons of cane per acre, a highly significant linear regression is obtained. The equation obtained reveals that a significant increase in sucrose percent cane occurs only after relative yields of cane reach over 133 as compared to a no-nitrogen application value of 100.
2. Different nitrogen sources, namely, ammonium nitrate, ammonium sulphate, and Uramon, produced no significant differences in influence on sucrose concentrations.
3. The application of phosphorus had no significant effect on sucrose percent cane when cane tonnage values were increased. In general both cane-tonnage and sucrose increases due to phosphate fertilizer applications were low.
4. The use of potash increased the sucrose concentrations of the cane only if cane yields were also increased.
5. The influence of fertilizers on increasing the relative yields of sucrose percent cane for each unit increase in the relative yield of tons of cane was 1.4 times greater for potassium than for nitrogen and 3.8 times greater than for phosphorus.
6. The minor element fertilizers produced no significant increases in sucrose content nor in cane tonnage.
7. Nitrogen applications increased polarization and degree Brix very significantly, and percent extraction to a lesser degree.
8. A deficiency of phosphorus significantly decreased sucrose (both in juice and in cane) as well as purity.
9. Potassium deficiencies produced highly significant reductions in available sugar in juice and cane, polarization, Brix, and purity. Percent extraction was not significantly influenced by use of potash fertilizers.
10. The roles of weather, soils, and variety as compared to fertilizers in influencing sugar and its components are discussed because their effects must be distinguished from the influence of fertilizers.

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Dr. R. D. Rege presented the following paper.

Paper

STUDIES ON THE INFLUENCE OF FLOODS ON CANE GROWTH AND QUALITY IN THE PAMBA RIVER VALLEY

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Among the cultivated crops cane is found to withstand the stagnation of water for a long period and accordingly the cultivation of cane in areas liable to floods and water logging is a common practice. So long as the growing point and the topmost leaves are above the level of the flood water no irremediable damage is caused to the growth of the cane crop during the period of this partial submergence. In his excellent book "Botany of Sugarcane" C. Van Dillewijin[1] has mentioned the following characteristics of the cane crop :

> "The wide range of soil moisture in which sugarcane is able to thrive is remarkable. Some varieties can withstand extreme drought ; others are confined to flooded areas like the Indian Cane Hathooni. Sewari and Co. 205 have been found growing in 4 feet of water. Das has published a picture of Co. 205 growing in India in a field which had been under water for five months. This cane had a brix of 18° at harvest. Noel Deerr has published a curious picture showing cane and rice culture combined with fishing in India."

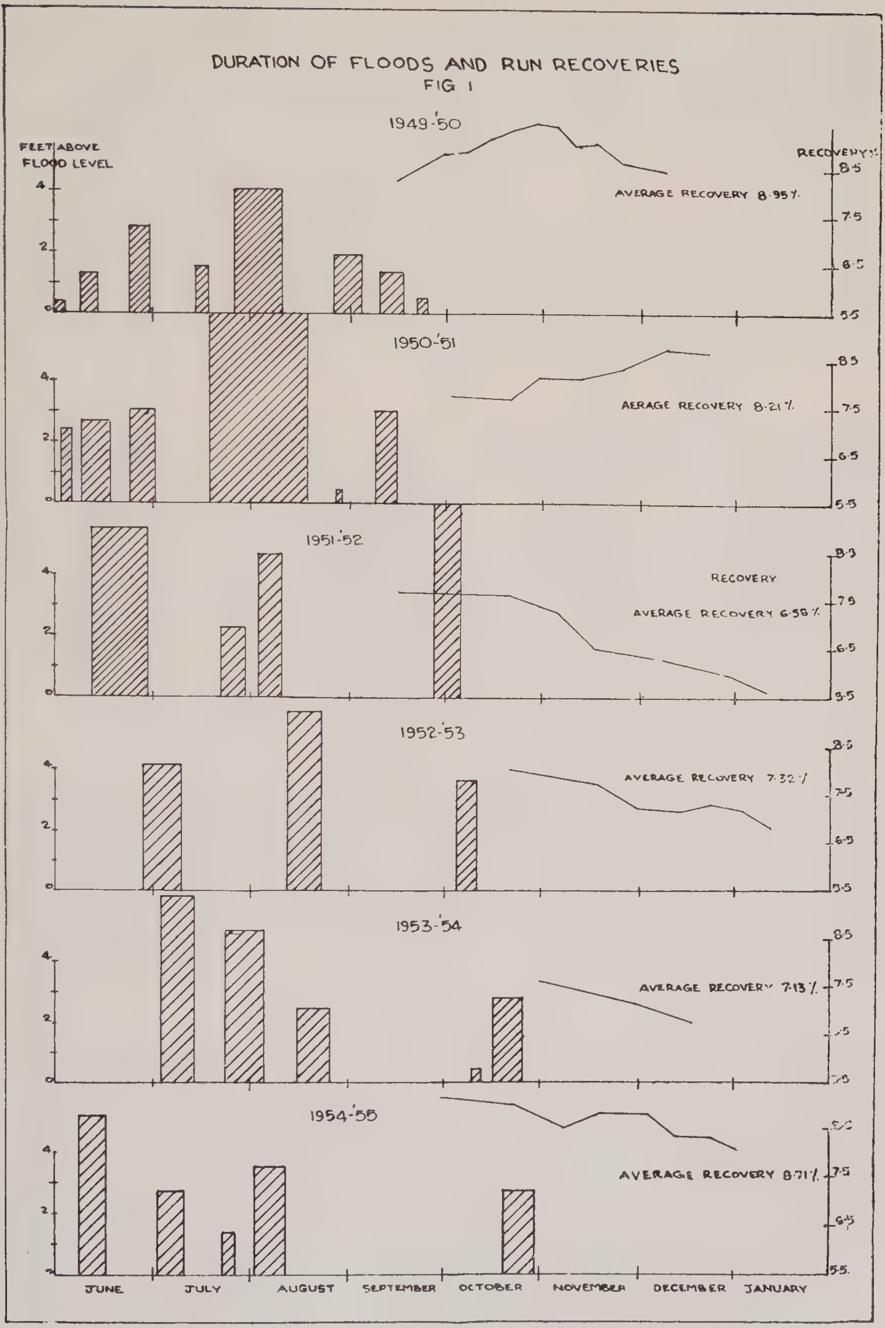
In India almost all the tracts which are liable to flooding get normally one or two floods during the early monsoon months of July and August which correspond to the grand period of growth in cane. There is, however, one tract in the Central Travancore, in which the Pamba River Factory is situated, which gets repeated floods from May to November varying from three to five in number.

The nature and the duration of the floods during each year are illustrated in Fig. 1. The normal river level lies between 82.5 to 84. It is estimated that about 20% of the cane area is flooded when the water in the boat basin rises to a level of 86, 30% at 88 and 50% at 89. With higher water level practically the whole area is flooded. The maximum period for which the flood lasts is about 20 days although the peak height of the flood does not last over three to four days. About 50% of the cane acreage remains under flood water for a week to 15 days during each flood depending upon the level of the plots and duration of the flood period. Extensive emergence of aerial roots in the submerged portions of cane is observed during the early floods followed by sprouting of aerial buds with later floods, specially after flowering. Any flood coming after September is received after the arrowing of cane. This flooding after arrowing is a unique characteristic typical of this tract only, as from the review of the literature and from the correspondence, which the Commonwealth Bureau of Horticultural and Plantation Crops, England, had with a number of cane research workers in the flood affected areas, it is observed that the cane crop in no other country receives any flood after the arrowing of the crop.

Crushing performance of the Pamba River Sugar Factory during the previous 5 seasons since 1949-50 has shown that while normal cane yields per acre are obtained every year in spite of varying periods of floods, the quality of cane, in general, remained not only low but showed a tendency towards fall with each run during the years when the flood was received after the arrowing of cane (Fig.1). The change in the date of starting of crushing during these years from the 16th of September to 2nd November had been ineffective in improving the sucrose content of cane. Considering that the crushing period varied during all these years from mid-September to about mid-January, which are the months of low temperatures, this progressive deterioration cannot be attributed to the high temperatures, which would be the case if the crushing was continued from mid-March onwards. It was, therefore, considered necessary to undertake detailed studies on the effect of flood on quality of cane, to evolve suitable measures for improvement in quality.

HISTORICAL

Almost nothing is known about the influence of floods on the cane quality. Khanna and Chakravarthy[2] refer to the adverse effects of prolonged flooding on sugar recovery and the difficulties created in processing. They found that whereas polarisation showed a large drop compared with normal cane there were increases in invert sugars, total colloids, gums, pectin, non-protein nitrogen and ash, the increases in invert sugars and gums being particularly large. On the other hand, according to Stevens[3] cane flooded with 4 feet depth of water for over two months, the growing tip at no time being submerged, made rapid recovery so as to pick up recoverable sugar immediately as water subsided. The alkacid Ribbon test showed juice to be quite normal very soon after receding of water so far as acidity was concerned. The rate of "pick up" in sugar was, however, slowed down to a considerable extent as time elapsed following receding of water but no deterioration in the cane quality throughout the period was observed. From his experience in Australia of the poorer drained sections of the sugarcane areas, Mr. King, Director, Bureau of Sugarcane Experiment Station, also maintains that waterlogged cane is not necessarily low in quality. In the Deccan Canal tract, where the cane crop is generally heavily manured with nitrogenous manures, excessive irrigation leading to flooding of the soil is practised for some time previous to the harvest of the crop with a view to improve the cane quality. Even in



DURATION OF FLOODS AND RUN RECOVERIES
FIG 1

the Pamba River valley canes from the loam soils continuously under water logged conditions for a period of over three months have shown good quality, while in the case of alluvial soils the reverse is found to be the case. The results obtained by the different workers are thus conflicting and appear to be dependent upon the cane variety under investigation and the composition of flood water.

CLIMATE

The climate is typically a tropical one with slight changes in the maximum and minimum temperatures throughout the year. The maximum temperatures varied from 84° to 91°F and the minimum from 70° to 77°F. The total rainfall average of 1949-53 has been 116 inches distributed monthwise as follows :—

Month	Rainfall in inches	Month	Rainfall in inches
January	0.47	July	20.89
February	1.72	August	13.53
March	1.89	September	13.65
April	5.90	October	13.69
May	13.55	November	6.05
June	24.14	December	0.46

The months of December to March are the driest months and June and July the wettest. From April onwards good rainfall is received. No irrigation is generally practised even during these driest months except a little by pots at planting time. The Company is making an intensive propaganda for irrigation of the crop during the months of December to March and have fixed at suitable sites electric pumps for supplying water at subsidised rates. A few cultivators are taking advantage of this facility of irrigation.

SOIL

The soils are alluvial formed by the gradual silting up of the sediments brought down by Pamba and other rivers during the floods on a laterite base. Soils vary greatly from sandy loam to clay loam. The lands on the banks of the rivers and low lying lands are generally rich in organic matter as well as mineral nutrients owing to the deposition of large quantities of fresh silt received during the floods. It is estimated that at the time of each flood such areas receive about 100 tons of silt per acre while higher areas get less than a ton per acre. The sub-soil is rich in iron sulphides. For easy classification the soils receiving practically no silt with floods are termed as loam and lands receiving large quantities of silt as alluvium. The average analysis of a few samples from the above-mentioned two types of soils as well as the silt are given below :—

	Loam	Alluvium	Silt
Total nitrogen%	0.126	0.183	0.206 to 0.450
„ P_2O_5%	0.163	0.199	0.249 to 0.368
„ K_2O%	0.163	0.193	0.393 to 0.486
Available P_2O_5 mgms. per 100 gms.	Trace	Trace	2.360 to 4.760
Available K_2O mgms. per 100 gms.	13.3	12.2	8.930 to 12.500
Humus%	0.38	1.67	2.352 to 2.542
CaO%	0.42	0.25	0.476 to 0.784
pH	6.4	6.1	
Ex. Ca.% me.	8.5	12.2	
Organic Carbon%	1.299	1.499	4.348
C/N ratio	9.36	10.34	20.61

It would be thus evident that the alluvial soils are richer in both humus and mineral nutrients. The availability of P & K is, however, lower than in the loam soils.

In the case of silt the samples showed a great deal of variation in its composition. Accordingly, the limits of the composition as obained for each constituent are given in the table. Taking on an average a deposit of 100 tons of silt per acre, the nutrients added to the soil even on the basis of the minimum analytical figures are as follows :—

	lbs.
N	461
P_2O_5	557
K_2O	880
CaO	1066
Humus	5286

The silt is thus highly fertile and supplies large quantities of nutrients to these soils. The high C/N ratio shows slow but continued availability of assimilable nitrogen to the crop, which while encouraging the growth of cane, is expected to adversely affect the quality.

EXPERIMENTAL

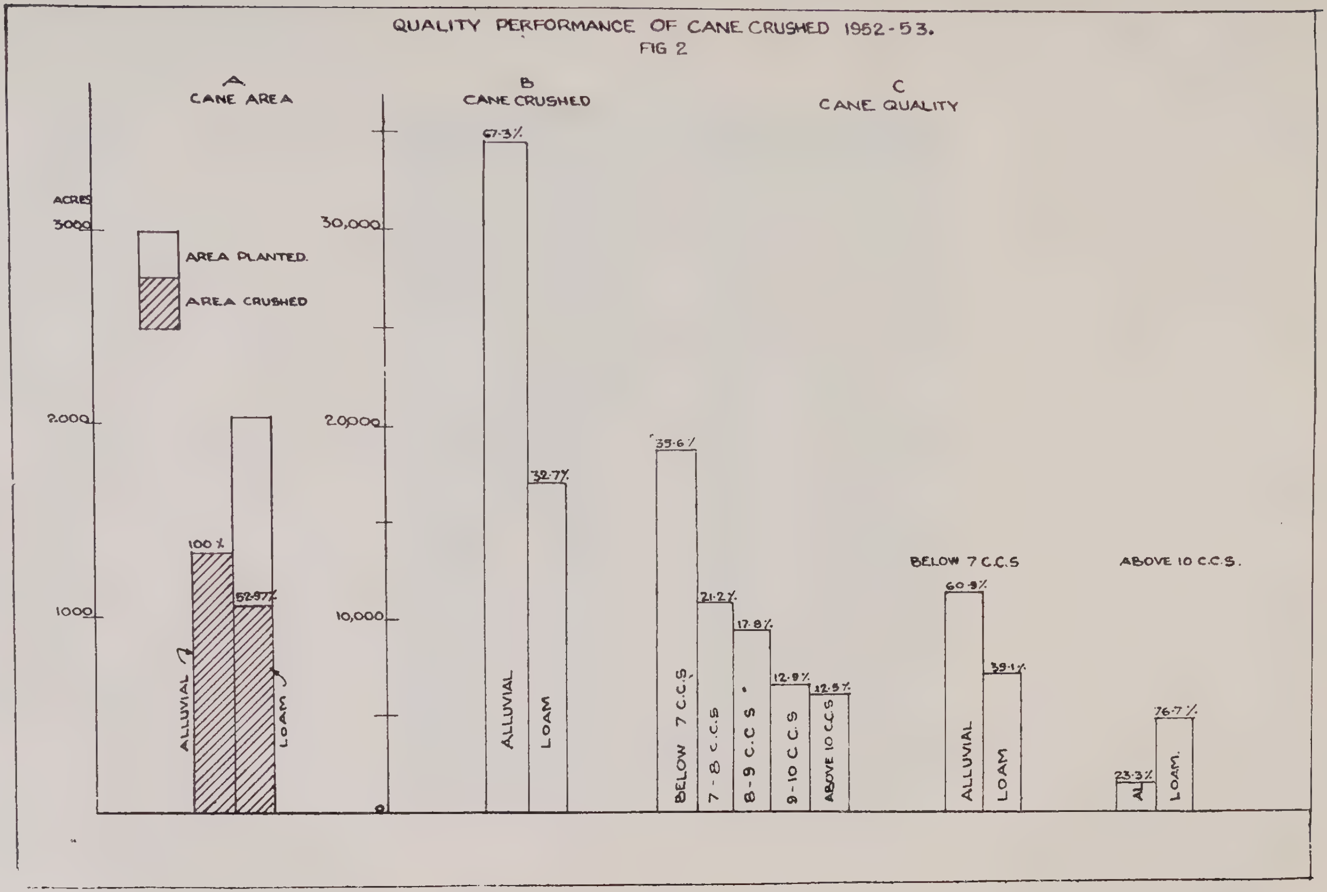
(1) **Cane Quality** : The performance of the Pamba River Factory during the last 6 seasons since its establishment is given below :—

Season	Tons cane crushed	Date of starting	% sugar on cane	Recovery of sugar % cane
1949-50	21,777	16.9.1949	11.68	8.95
1950-51	43,349	3.10.1950	10.45	8.21
1951-52	67,515	17.9.1951	9.14	6.58
1952-53	53,053	20.10.1952	9.71	7.52
1953-54	30,694	2.11.1953	9.34	7.10
1954-55	55,992	1.10.1954	10.78	8.72

A progressive deterioration in cane quality is evident from year to year except during the last year of 1954-55. Before the establishment of the factory sugarcane was being mainly cultivated in this tract for the manufacture of jaggery and the grower was well aware of the necessity of growing cane in the high lands in order to get high quality juice for the production of good quality jaggery. Almost all the area under cane was, therefore, in the highland previous to the establishment of the factory. Once the growers found that the sugar factory was purchasing cane on weight basis, irrespective of the quality, they extended their cane cultivation to the freshly precipitated alluvial soils, as the cultivation of cane not only enabled them to get a higher yield per acre but also facilitated the transport of cane to the factory. It is estimated that, due to the fertile nature of silt, the alluvial soils generally give an average of 26 to 28 tons of cane per acre as against 16 to 20 tons on loam soils. Further as the transport of cane is water-borne through the rivers and as there are very few roads to the water fronts, the cultivation of cane in the alluvial soils, which are mainly on the banks of the rivers, facilitates the transport on head-loads to these water fronts.

A detailed survey was taken during the year 1952-53 with regard to the extent of cane cultivation in alluvial and loam soils. Out of the total area of 3,416 acres under cane during this year 40% were found to be on alluvial soils. It is interesting to note that, while cane from all this area on alluvial soils had come to the factory, cane from only 52.9% of the acreage on loam soils was received by the factory, the rest being utilised for jaggery making. Further, on the basis of the differential yield per acre in the alluvial and loam soils 67.3% of the total supply of 53,053 tons of cane received during that year was from the alluvial soils only. It is thus obvious that cultivators do realise that cane from alluvial soils is not suitable for jaggery manufacture and they cultivate the crop mainly for supply of cane to the factory.

Detailed quality tests were also carried out during that season of the cane bundles received from each cultivator. The unique feature in the case of this factory is that all cane arrives at the factory by *valloms* loaded in bundles tied by chains and kept on either side of the central beam of the boats. The six chains are hooked to the spreader bar of the Henderson Crane and the bundle is lifted and weighed and put on the unloading platform. The hooks are loosened and the cane falls on the auxiliary carrier. The feeding of cane to mills is thus done ryot by ryot and the supply of each ryot is about 3 to 4 tons. As soon as the cane falls from the auxiliary carrier to the main carrier, a signal light is given to the factory that the concerned ryot's cane as per the card supplied has started falling on the carrier. The signal is noted in the card by a number as indicated by a pointer to a rotating cycle wheel kept near the crusher. The cycle wheel is rotated by a belt from a small wheel fitted on the head shaft of the main carrier inside the factory and it is so adjusted that when the main carrier travels the entire distance from the auxiliary to the crusher, the cycle wheel rotates once. The wheel is divided into 8 equal divisions and marked 1 to 8 with the fixed portion on the main structure. The number of the cycle wheel at the time of signal, i.e., at the time of



QUALITY PERFORMANCE OF CANE CRUSHED 1952-53.
FIG 2

cane dropping on the main carrier is noted on the card and when the cycle completes the next roatation and indicates the same No. at the pointer the bundle of cane of the particular ryot is ready for crushing. A sample boy posted at the crusher collects the representative sample during the entire length. The ending of each bundle is the starting of the next bundle and a fair provision is made to eliminate sampling juice of the mixed cane of the two adjacent ryot's bundles.

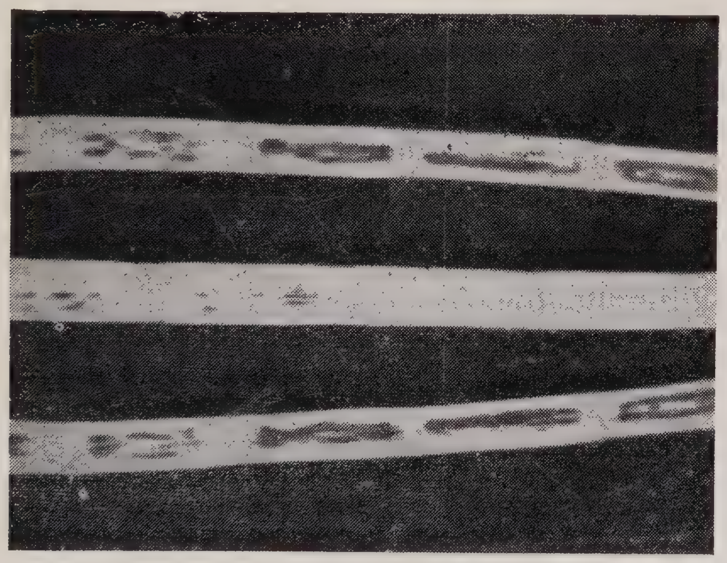
The data of C. C. S. calculated on the laboratory analysis of the crusher juice for these two soils types are illustrated in Fig. 2. It would be seen that 60·9% of the cane from the alluvial soils gave a recovery below 7% while 76.7% of the cane from loam soils gave a recovery of over 10%. In later years only brix was determined per individual bundle and the data obtained during the year 1954-55 have also confirmed the low quality cane in the case of the alluvial soil. The brix in the case of 82% of the cane supply from the alluvial soil was below 16, while in the case of the loam soil this percentage was 33.1 only. The sudden rise in the recovery obtained during this year is, however, mainly due to the greater diversion of cane from the loam soils owing to the fall in the price of jaggery. Out of the total supply of 54,311 tons, 62.58% was from loam as against 32.7% during the year 1952-53. It would be thus evident that by mere switch over of the cane supply from alluvial to loam soils a great deal of improvement in the quality of cane received by the factory could be achieved even though both these soils are simultaneously flooded. Since the season 1953-54 the Pamba River Factory has introduced a quality bonus on the basis of 3 annas for every one-tenth increase in brix over 17° with a view to develop quality sense among the cane growers. It is expected that as a result of this bonus system more cane may be grown in the loam soils for supply to the factory. It must be, however, realised that cane cultivation in alluvial soils has come to stay and considering the appreciable supply of cane, which would be received by the factory in future years from this soil also, it would be necessary to evolve suitable methods of cultivation to improve the quality of cane in this soil as well.

(2) **Cane Varieties.** The varieties in general cultivation at present are POJ. 2725 and Co. 349. The former variety was introudced mainly on the consideration of its being suitable to paddy areas, as it was being grown under similar conditions in Java. Owing to its early maturing characteristic it is however mainly grown on highlands from August to October to avoid high floods and is mostly utilised for jaggery making in the beginning of the season. Co. 349 is a vigorous growing cane, doing well even under water logged conditions. It is generally planted from December onwards and the planting period extends even up to May. Late plantings from March onwards are mainly meant for jaggery manufacture and are entirely restricted to highlands. The variety is late maturing and lodges badly, especially in the alluvial soils. Ratoons are often disappointing and give poor yields. In the supply of cane to the factory the proportion of this variety has fluctuated from 69 to 87% during different years and accordingly it is of very great importance. Critical studies of a large number of canes of this variety coming to the factory showed large lesions, either red, brown or black, heavy pith formation and cavities which were more severe and common in the alluvial soil (Plate 1). Laboratory analysis of the juice have shown a fall in quality due to these lesions.

	Brix	Pol	Purity
Healthy cane	16.87	14.37	85.18
Partially diseased cane	16.10	13.92	86.45
Heavily diseased	15.06	12.25	81.34

Detailed investigations have shown that these lesions are not caused by any fungus or virus infection and are considered to be due to some physiological disorder caused by repeated floods. In the case of POJ. 2725, only small red dots at the nodes are often observed. Further, these symptoms of physiological disorder are hardly seen in March or later plantings of Co. 349. These late plantings are mainly meant for jaggery manufacture during the months of March and April and are entirely restricted to the highlands with a view to avoid high floods. A majority of the canes in these plantings do not also flower. The laboratory analysis of the canes from these plantings in next March and April have shown the possibility of getting high quality cane giving 10.5 to 11.5 C.C.S. In order to see whether such late plantings in alluvial soils would also show an improvement in quality, a small area was planted with Co. 349 in the month of March 1954. The crop made vigorous growth and had attained sufficient height even before the first flood to escape complete submergence. The laboratory analysis of the canes in March 1955, i.e., after a period of 12 months, however, showed very poor quality as compared to those of similar planting from the loam soil.

PLATE 1

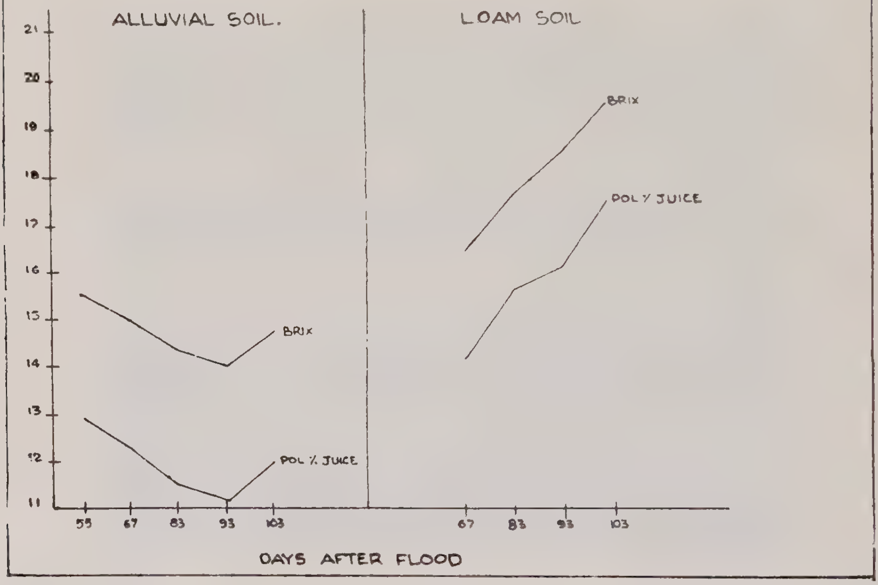


	Brix	Pol	Purity
Alluvial soil	14.48	11.06	76.38
Loam soil	20.72	18.65	90.01

It is thus evident that no improvement in the cane quality can be achieved by delaying the planting in the case of the alluvial soil.

As the factory starts crushing normally during the months of September/ October, the major supply of cane is of 10 to 11 months of age. A few plots of Co. 349 planted in January were, therefore, allowed to stand after the crushing season was over in December 1953, both in the alluvial and loam soils and the canes were periodically tested in the laboratory for quality over a period of 103 days till mid-February after the last flood in October. The data are illustrated in Fig. 3. It would be interesting to note that while there was a progressive deterioration in the cane quality in case of the alluvial soil, the same variety had shown prorgessive rise in the loam soil showing a brix of 19.5° and Pol of 17%. The juice analysis for mineral nutrients have also shown a great deal of variation in the case of both these soils.

SOIL TYPE - EFFECT OF FLOOD ON CANE QUALITY
FIG 3



	N	P_2O_5	K_2O	CaO
	(mgms.	per 100	cc.	of juice
Loam soil	9.28	31.44	55.59	19.60
Alluvial soil	21.73	15.99	45.15	28.47

From the above analytical data it is evident that besides the high absorption of nitrogen the unbalanced nutrition of major elements NPK is evident in the case of the alluvial soil. According to Dillewijn (Botany of Sugarcane) increasing application of nitrogen exerts a depressing effect on the percentages of ash, phosphorus and potassium in the cane juice. Only the element calcium is increased.

The poor quality performance of Co. 349 in the alluvial soil is not thus due to the floods which are common for both loam and alluvial soils but to the fertile silt which is deposited by these floods in alluvial soils.

With a view to explore the possibility of getting over the deleterious effect of the silt on the cane quality, about thirty varieties capable of withstanding flooded conditions have been obtained from Coimbatore, Bihar and Bombay and these are under different stages of testing and multiplication in this soil. Among these Co. 449 and Co. 785 are found to be very promising as besides showing a superior quality performance over the existing varieties of Co. 349 and POJ. 2725 they have shown no trend towards deterioration in quality due to the late flood, common in these existing varieties in cultivation. The data are given below :—

		Alluvial Soil		
		Brix	Pol	Purity
Co. 349	Before flood	16.56	14.63	88.35
	21 days after	16.21	13.75	84.83
POJ. 2725	Before flood	16.35	14.31	87.47
	18 days after	15.58	12.78	83.65
Co. 449	Before flood	18.04	16.24	89.98
	18 days after	18.83	16.52	87.75
Co. 785	Before flood	18.60	15.81	85.00
	25 days after	18.80	16.41	87.29

While both Co. 349 and POJ. 2725 have shown a fall in Pol after the floods, these two new varieties have shown a tendency towards an increase. Both these varieties also appear so far to be free from brown or red lesions observed in Co. 349.

In view of its highly promising performance, seed of Co. 449 was imported from Nellikuppam to cover an area of 10 acres during the season of 1954. Comparative plots of this variety and Co. 349 were selected from the alluvial soil to supply sufficient quantities of cane of each of these varieties for one hour's continuous crush. The following are the results of the mill test :—

	Brix	Pol	Purity	C.C.S.%
Co. 449	18.63	16.30	87.49	11.44
Co. 349	14.26	10.96	76.86	6.97

In the case of the loam soil both Co. 449 and Co. 785 are also found to be distinctly superior in quality over Co. 349 as shown below :—

	Brix	Pol	Purity
Co. 349	17.20	15.16	88.14
Co. 449	20.49	18.50	90.60
Co. 785	22.15	20.49	92.52

In view of such good performance of both these varieties it was proposed to multiply these varieties rapidly to cover all the area under cane as quickly as possible. Accordingly seed of Co. 449 for about 60 acres has been imported from

Nellikuppam during November/December 1954 and it is expected that with the material available from the last year's crop about 100 acres will be under this variety during 1955. The rate of multiplication is rather slow as due to the floods about half the cane is not suitable for planting. The seed material of Co. 785 was not available from outside and the area under this variety would be about 5 acres during 1955.

(3) **Manuring** : Considering the differential fertility status of the alluvial and loam soils the variation in their response to manuring is expected. Accordingly a number of extension trials were undertaken in both these soils in the cultivator's fields with NPK singly as well as in combination. 30 such trials were conducted in the loam and 30 in the alluvial soil during 1954. In the case of loam soil the quantity of nitrogen per acre was kept at 100 lbs. N, while in the alluvium it was reduced to 50 lbs. N. The quantities of phosphate and potash were kept at 100 lbs. of P_2O_5 and 100 lbs. of K_2O respectively in the case of both these soils which gave a proportion of 1:1 of NP & NK in the case of the loam soil and 1 : 2 of these constituents for the alluvial soil. The harvest data as average of these 30 trials for each of these soils are given below :—

	Loam				Alluvium			
	Cane tons per acre	Brix	Pol	Purity	Cane tons per acre	Brix	Pol	Purity
N	29.85	16.86	14.12	83.75	33.48	14.76	11.38	77.10
NP	30.48	16.96	14.06	82.90	34.94	14.49	10.93	75.43
NK	32.21	17.01	14.45	84.95	37.29	14.72	11.42	77.58
NPK	31.06	16.87	14.28	84.65	37.08	14.78	11.53	78.01

The results have shown that, while there is a slight beneficial effect of potash on cane tonnages especially in the alluvial soil none of the treatments are found to be of any advantage in improving the quality of cane. It is interesting to note that, while in the case of the alluvial soil the cane yields per acre are higher in spite of 50% reduction in nitrogen, the quality of cane still continues to be much poorer than in the case of loam soils. It is thus evident that even this small dose of nitrogen in the case of alluvial soil is excessive, clearly indicating the availability of large quantities of nitrogen in the freshly deposited silt in this soil.

The experimental work with the soil application of trace elements such as copper sulphate, manganese sulphate, zinc sulphate and borax has not shown any beneficial effect both on cane tonnages and on quality in the case of the alluvial soil. It has not been thus possible so far to evolve any suitable manurial practice which would lead to an improvement in the quality of cane in the alluvial soil and further work is in progress.

(4) **Cultural** : The general practice in this tract is to plant cane in pits with 3 to 4 top setts per pit. The pits are not often in a straight line and the distance between the pits varies from 1½ to 2½ ft. At the time of manuring the soil is dug up and these shallow pits are filled up. No earthing up is done and in consequence the

crop lodges very badly. Demonstration trials with trench planting followed by earthing up of cane were, therefore, undertaken at a few places. The trench planting is of great advantage during the drought period as it facilitates irrigation and utilises much less quantity of water than in the case of flat planting. The harvest data of these plots have shown great improvement in the cane quality as a result of the earthing up operation. The relevant data are given below :—

	Brix	Pol	Purity
Earthed	18.44	16.49	89.43
Not earthed	17.24	14.75	87.35

SUMMARY AND CONCLUSION

In Central Travancore, in which the Pamba River Sugar Factory is situated, cane cultivation is characterised by repeated floods from May to November varying from 3 to 5 in number. Any flood coming after September is received after the arrowing of cane. From the review of the literature it is found that flooding after arrowing is quite unique typical to this tract only and is not observed in any other cane growing country.

Considering the average performance of the sugar factories in other parts of India, the recovery of sugar from cane obtained by the Pamba River Factory has been extremely poor. Further a progressive deterioration in the recovery was obtained from year to year. Detailed investigations were therefore conducted during the last few years and the results so far available are summarised below.

(1) The progressive fall in the sugar recovery during the period of crushing is found to be mainly due to the increasing supply of cane from the freshly precipitated alluvial soils. These soils are covered with large quantities of fertile silt with each flood, leading to luxuriant growth in cane and production of high cane tonnages per acre. The quality of cane from such soils is, however, very poor and is further adversely affected by late floods. Periodical laboratory analysis of cane for a number of days after the flood have shown a continuous fall in the sucrose content in cane. From the analysis of juice for mineral constituents it is found to be due to the unbalanced nutrition caused by high absorption of available nitrogen from the soil.

(2) Some immediate improvement in sugar recovery is quite possible by getting a higher supply of cane to the factory from the loam soil in the highlands. Most of the cane grown in such soils is high quality cane; but it is utilised for jaggery manufacture and in consequence is not generally available for crushing to the factory. Owing to the fall in jaggery price, however, during the season of 1954-55 there had been a great diversion of this cane to the factory and the rise in recovery observed during this year is mainly due to the large supply of cane from the loam soil, which has come to 62.6% of the total supply as against 32.7% during the season of 1952-53. It is observed that these loam soils although flooded for the same period as the alluvial ones do not practically receive silt in the flood

water. Late floods do not also cause deterioration in the sucrose content of cane. On the other hand, there has been a progressive rise.

(3) The major supply of cane to the factory is from the variety Co. 349. Critical studies of a large number of cane coming to the factory have shown these to be affected by large lesions either red, brown or black, pith formation and cavities which are more severe and common in the alluvial soil. These lesions are considered to be due to physiological disorder caused by repeated floods and not to fungal or virus infection. The deterioration in quality appears to be partly due to these lesions. The other variety POJ. 2725 being mainly grown in the highlands do not show these lesions to a great extent.

(4) Trials with a large number of varieties obtained from Coimbatore, Bihar and Bombay have shown that a great deal of improvement in the sucrose content of cane is possible even in the alluvial soil by the introduction of other varieties such as Co. 449 and Co. 785. The large scale factory mill test for an hour of Co. 449 obtained from the alluvial soil has given C.C.S. of 11.44% as against 6.97% from Co. 349. Both these varieties are also found to be superior in quality to Co. 349 in the loam soil. They also give good tonnages almost equal to those of Co. 349. A seed multiplication scheme has been, therefore organised to multiply these varieties rapidly.

(5) With regard to manuring, differential manurial technique is considered necessary for these two types of soils. In the alluvial soil the reduction of the nitrogenous dose by 50% has still maintained the yield of cane higher than in the loam soil. The quality, however, still continued to be poorer than of the canes from the loam soil even receiving double dose of nitrogen. Phosphate and potash as well as trace elements have been also ineffective in improving the quality. Further work is in progress to evolve suitable manurial techniques for these soils.

(6) The introduction of trench planting and earthing up of cane has brought about a distinct improvement in the sucrose content of cane. Further this cultural method facilitates proper irrigation of cane and also assists in the quick draining of water once the flood starts receding.

(7) The conflicting evidence about the effect of water on th equality of cane obtained by the various workers appears to be due to the composition of the flood. It is observed that the deterioration in quality is mainly caused by the fertile silt deposited during flooding. In areas which are, however, flooded with water free from silt, the late flood even after the arrowing of cane is not found to be harmful.

The authors wish to express their great appreciation for all assistance given by Mr. P. Hadfield, Managing Director, Parry & Co. Ltd., and by Mr. A.W. Banks, General Manager of the Pamba River Factory. They are also thankful to Mr. Kovvoor, the Cane Superintendent and his staff and the Laboratory Chemists of the factory for their excellent co-operation in the conduction of experiments and the collection of data discussed in this paper.

DISCUSSION

In reply to a question by Dr. Evans whether the water was moving or stagnant as in the former case aeration would be possible while in the latter there would be no aeration resulting in a tendency for roots to come up and damage being caused by the toxic product of decomposition of roots, Dr. Rege said that in spite of water stagnation for over 2 months in loamy soils with silt deposition toxic effect due to decomposition of roots was entirely absent.

Dr. Sen presented the following paper.

Paper

A SIMPLE DESIGN OF REFRACTOMETER PUNCTURING NEEDLE FOR ITS QUICK AND EFFICIENT APPLICATION IN SUGARCANE HARVEST CONTROL ON THE BASIS OF MATURITY THROUGH HAND REFRACTOMETER

S. C. Sen

Indian Institute of Sugar Technology, Kanpur, India

Due to the fact that sub-tropical India is characterised by progressive ripening of sugarcane right from the middle of October to almost end of March, Khanna and Sen[1] were able to successfully apply the Hand Refractometer in harvest control in succession of ripening in sugar factory areas in Bihar.

The maturity survey in connection with the harvest control has to be completed within a very short period not exceeding on any account 6-8 days, preferably, within 4-5 days, else the time factor will vitiate the cane quality. For timely completion of the work within 8 days in a reserved area having 20,000/30,000 plots under cane, Khanna and Sen divided the area into 40-50 zones, each comprising roughly 500/600 plots. The survey party for each zone engaged by them consisted of a Refractometer Analyst, an Amin and a labourer. This team moved from field to field and completed a plotwise quality survey, covering all plots in the area assigned to it, the daily progress being 35/40 plots under cane. The quality assessment procedure consisted in selecting 10 whole clumps at random in each plot of $\frac{1}{30}$ acre or more clumps at random of bigger area, the number being increased proportionately to area and observing refractometer brix readings on the juice extracted from the middle internode of all millable canes in all the clumps. The mean of all these readings represents the brix value per plot. The work was distributed to the team in the following manner :

(*i*) the labourer punctured the middle internode of the cane by means of the puncturing needle through which only one-two drops of juice could be extracted.

(*ii*) the Refractometer Analyst noted the refractometer brix readings of the juice extracted by the labourer.

(*iii*) The Amin wrote down the readings on the printed form, besides entering other information pertaining to the plot.

The plotwise refractometer brix data collected by the party were passed on to calculate the average brix values per plot, which is done by adding the refractometer brix readings of all the millable canes in all the clumps and dividing the total value by the number of canes examined. All these meant a huge recurring expenditure of about Rs. 5000 to Rs. 6000 spent on 2000-2500 man days, stationery etc. and a non-recurring expenditure of Rs. 16,000 or so for the purchase of 40 hand refractometers. The recurring expenditure on man days etc. and non-recurring expenditure on refractometers may be greatly curtailed by simply designing the puncturing needle.

Khanna[2] was the first to design the cane puncturing needle with hypodermic syringe as early as 1937 in India, but unfortunately, the working of the syringe with spring arrangement was not found very successful. The Zeiss puncturing needle is now greatly modified for easy and quick operation in harvest control by the author. The details of it are given below and are shown in Diagram 1.

1. The groove of the puncturing needle from the pointed portion is made sloping and is provided with a hole about 3/32″ diameter at 3.5 centimeter apart. The pointed portion of the needle is slightly raised in order to make the extracted juices flow smoothly through the groove and pass through the hole to the reservoir.

2. The lower portion, just below the hole, is projected at 105°, having threads up to quarter of an inch, in order to fix the threaded reservoir. The threaded reservoir like the top may also be threaded at the bottom being fixed with another threaded cover.

3. The threaded reservoir is attached in such a way that it does not touch the cane stem during operation.

4. A number of extra threaded reservoirs with threaded covers or rubber bungs or preferably hard glass tubes, 2″ in length and $\frac{1}{4}$″ in diameter with rubber corks are provided either to attach new threaded reservoirs, to the needle or to attach the same reservoir after transferring the juice to a glass tube previously numbered.

5. The other end of the puncturing needle is fitted with either a flat ebonite or hard rubber handle for easy operation.

This greatly simplifies the survey work. Only one intelligent and conscientious worker can do the entire job of the team of three even with more efficiency. The worker is to be provided with a puncturing needle, a few extra reservoirs and a number of glass tubes. All these glass tubes are numbered serially. The worker punctures the middle internode of all the standing canes of the requisite whole clumps of a plot, depending on the acreage, collects the juices in the reservoir all together. After the complete survey of each plot, the reservoir is detached and is immediately transferred to a glass tube fitted with a rubber cork so that no juices can trickle after covering. If per chance a reservoir gets full with juices of canes of a plot before completion of the survey, another reservoir is fixed up and juices are collected. At the time of brix reading, the juices of both the reservoirs are mixed together to get the representative brix reading of the plot. Before passing to the next plot, the worker records all the specifications of the field, namely, cultivator's name. Thana No., Khesra No., variety, acreage, probable yield in the proforma as provided in Appendix No.III in the paper of Khanna & Sen (1953) under the same number, the reservoir is numbered. In this way, the worker goes on collecting juices from field to field from eight in the morning till two in the afternoon at a stretch. A team for convenient and efficient work should consist of four such conscientious workers instead of one for proper sampling of canes per plot. Four workers enter the plot from four sides of the field and extract the juices in their respective needle reservoirs. After completion of the work, the juices of 4 reservoirs are all well mixed and kept in a numbered glass vial as described. A driver is directed to move in a jeep from field to field to collect the reservoirs full of cane juices from a number of workers and pass on to the chemist in the laboratory, positively between three and four in the evening, else the juices may ferment. Cane juices usually do not ferment in winter within 8-10 hours. Therefore, refractometer brix readings of juices of these reservoirs collected within 7-8 hours by a chemist with the help of a refractometer will be reliable. The refractometer brix readings of sufficient juices in the laboratory at convenience will indicate better and accurate value than the readings on the field, where the refractometer may not be properly cleaned after each reading. In this way the entire survey can be easily conducted with a very limited number of refractometers besides the readings will be more representative and more reliable as they are collected from all directions of the plot and recorded in the laboratory by qualified chemists. In addition, since the juices are to be examined in the laboratory cooking of the results by unreliable workers will enormously be reduced.

A few experiments have been carried out to assess the suitability of such refractometers both in the laboratory and on the field, just to observe whether the refractometer brix of the mixed juices collected in the reservoir compares with the mean value of the juices extracted individually by ordinary puncturing needle.

EXPERIMENT

To find out the relation between the calculated average value of refractometer brix collected individually through the puncturing needle and the value of ref. brix of mixed juices collected in the reservoir of newly designed needle, a number of canes were brought to the laboratory and tested. With the usual puncturing needle all the internodes of a cane were punctured and the refractometer brix of individual internodes was recorded separately. The values were added and average value was determined by dividing the total value with the number of internodes punctured. One drop of the juice on the other hand of all the individual internodes of the same cane was extracted through the newly designed needle and collected in the reservoir. The refractometer brix of the composite juice sample was recorded. These two values thus obtained of a number of canes were statistically analysed and the difference between these two readings was found to be non-significant.(Table I). This shows that the collection of composite samples through the newly designed needle in the reservoir would give reliable results of the plot. The detailed figures are not given to economise space.

TABLE I

No. of pairs	Mean of average value of juices (A)	Mean of the value of mixed juices (B)	Diffference D (B-A)	$ED=E^2A+E^2B$	't'
50	18.48	18.53	0.05	0.341	0.147

The significance between the readings of the two puncturing needles has been tested by calculating $t=D/ED$; where D is the difference between the two means and ED the standard error of this difference. 't' from the table at 5% level and 98 degrees of freedom is 1.98, which is much higher than the obtained value of 't' in this case. The result is therefore highly non-significant. The B whose operation is more simple, economical and quicker would be preferred to instrument A. To test more adequately, the refractometer brix of the middle internode of all the canes of 5 whole clumps from a plot of 1/80th acre was individually determined and the mean value obtained by dividing the total readings with the number of canes examined. This was compared with the refractometer brix value of the mixed juices collected from the same middle internodes of all the canes previously punctured, in the reservoir of the newly designed needle. In this way a number of fields were tested and the data were statistically analysed (Table II).

TABLE II

No. of pairs	Mean of average value of juices (A)	Mean of the value of mixed juices (B)	Difference D (B-A)	$ED=E^2A+E^2B$	't'
50	18.88	18.85	0.03	0.298	0.10

The relationship between the average refractometer brix value of all the canes of five whole clumps and the refractometer brix value of the mixed juices collected from the same place of all the canes of 5 whole clumps was determined. The significance test was determined from $t=D/ED$.

The difference is very highly non-significant. This definitely shows that the newly designed needle can be very suitably used in the field for sugarcane harvest control.

To test how long the juices collected in the reservoir of the puncturing needle remain undecomposed, cane juices were kept in vessels of nickel, brass, aluminium, iron and glass and tested for their refractometer brix at an interval of 2 hours remain for 15/20 hours at a stretch. It has been observed that the refractometer brix remains unchanged upto 8-10 hours during December and that the brix gradually increases showing thereby that fermentation has taken place. The juices kept in glass vessels remained undecomposed for longer periods compared to metallic vessels, and therefore, it is recommended to transfer the juices collected in the threaded reservoir to hard glass tubes or to small empty glass phials.

TABLE III

SHOWING THE DECOMPOSITION OF CANE JUICES WHEN KEPT IN DIFFERENT METALLIC VESSELS DURING JANUARY

Particulars	Juices are crushed at 10.0 hours and examined after 2 hours interval										Remarks
	12.0	14-0	16-0	18-0	20-0	22-0	24-0	2-0	4-0	6-0	
Nickel vessel	19.6	19.6	19.6	19.6	19.6	19.8	19.8	20.0	20.0	20.0	The same experiment was repeated in different months and the results indicated the same trend.
Brass do	19.6	19.6	19.6	19.6	19.6	19.6	19.8	19.8	20.0	20.0	
Glass do	19.6	19.6	19.6	19.6	19.6	19.6	19.6	19.6	19.8	19.8	
Aluminium do	19.6	19.6	19.6	19.6	19.6	19.6	19.8	19.8	20.0	20.0	
Iron do	19.6	19.9	19.6	19.8	19.8	19.8	20.0	20.0	20.2	20.2	

The cost of surveying a reserved area of 20,000 plots with this newly designed needle is as shown below :

1. *Non-recurring*

	Rs.		
5 Hand Refractometers Zeiss @ Rs. 400 each	2000	0	0
100 modified puncturing needles at Rs. 5 each	500	0	0
30 glass hard glass tubes ($2'' \times \frac{1}{4}''$) with good corks	200	0	0
Total	2700	0	0

2. *Recurring*

	Rs.		
100 conscientious workers @ Rs. 2/8/- a day for 6 days	1500	0	0
5 Chemists or Analysts @ Rs. 4 a day for 10 days	200	0	0
Cost of typing for survey the data of 20,000 plots	200	0	0
Miscellaneous and 2 reams paper	100	0	0
Total	2000	0	0

The cost of paper will also be greatly curtailed as the form field No. 1 used by Khanna and Sen will not at all be required. Now, only the form calculation No. II will be used, for both survey and calculation work.

5 Chemists will work with the refractometers for 6 days only and in 4 days, they will arrange the plotwise brix data as recorded by refractometers in succession of ripening. For 20,000 plots, the typist has to type 20,000 lines. If 20 lines are covered in a page, only 1000 sheets will be required to cover the survey of the entire area of 20,000 plots. The entire survey of 20,000 plots, therefore can be easily completed within Rs. 4700 in all, including Rs. 2700 non-recurring expenditure and Rs. 2,000 recurring expenditure, in place of over Rs. 20,000 as shown by Khanna and Sen. It has already been stated by Khanna and Sen that scheduled crushing on the basis of succession of ripening is capable of yielding rich dividends to the Industry. They have shown that to a factory crushing 25 lakh maunds of cane a season it would mean an additional return of 4 lakh rupees. When such is the huge profit, it is worthwhile and rather advisable for all the factory owners to adopt this procedure which costs practically nothing, *i.e.*, only Rs. 4700 in the first year and Rs. 2700 in the successive years. After 3-4 years of such survey work, the millowner will easily come to know the variation in juice quality of his reserved area.

SUMMARY

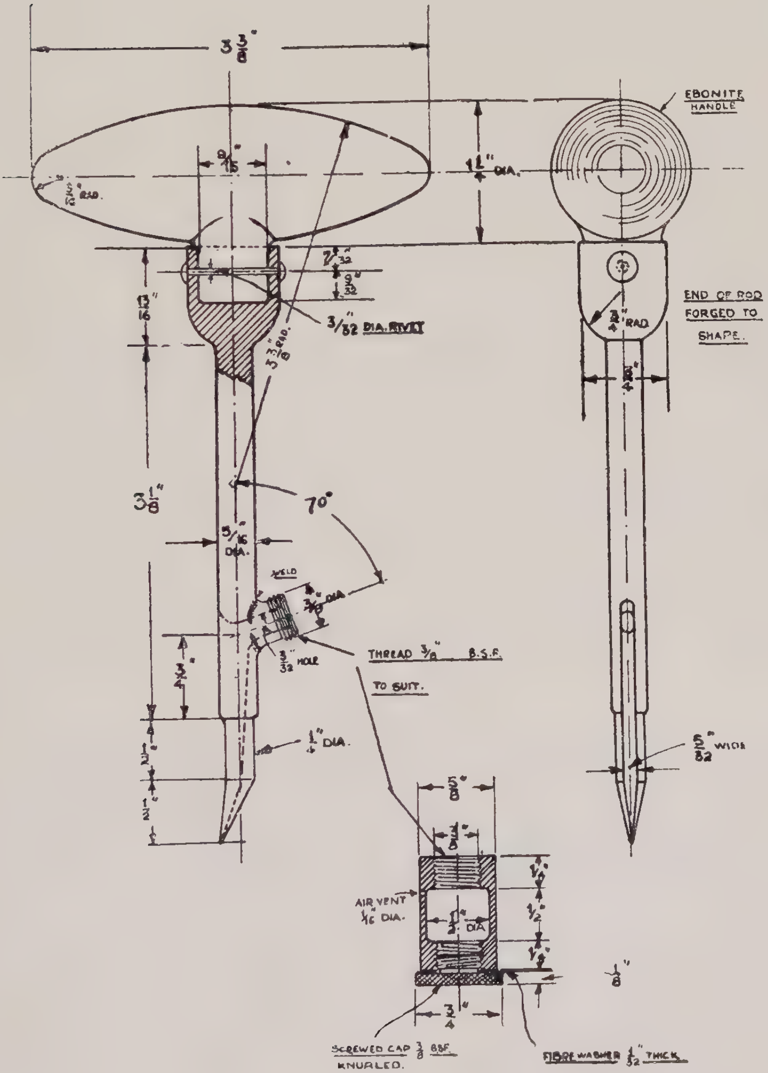
1. The newly designed needle can very well be used in sugarcane harvest control in succession of ripening at a nominal cost of Rs. 4700 in all for a reserved area having 20,000 plots.
2. The difference between the average value of refractometer brix taken individually at the middle internodes of all the canes of 5 whole clumps of a plot of 1/80th acre and the refractometer brix value of the mixed juices collected from the same middle internodes of all the canes is very highly nonsignificant.
3. The refractometer brix value of crushed juice remains unchanged for 8-10 hours during winter when the survey is likely to take place, and glass vessel was found the most suitable.

ACKNOWLEDGEMENT

The author is deeply indebted to Dr. K.S.G. Doss, D. Sc., F.R.I.C., F. Inst. P., F.A.Sc., Director, Indian Institute of Sugar Technology, Kanpur for his

SUGAR CANE PUNCTURING NEEDLE
WITH
SAMPLING CAPSULE

(MAT. STAINLESS STEEL.)


3 3/8"
9/16"
3/16" RAD.
1 1/4" DIA.
EBONITE HANDLE
7/32"
9/32"
13/16"
3/32" DIA. RIVET
3 3/8" RAD.
END OF ROD FORGED TO SHAPE.
3/4" RAD.
3/4"
3 1/8"
70°
5/16" DIA.
WELD
3/8" DIA
3/32" HOLE
3/4"
THREAD 3/8" B.S.F. TO SUIT.
1/2"
1/2"
1/4" DIA.
5/32" WIDE
5/8"
3/8"
1/4"
AIR VENT 1/16" DIA.
1/2" DIA
1/2"
1/4"
1/8"
3/4"
SCREWED CAP 3/8 BSF. KNURLED.
FIBRE WASHER 1/32" THICK.

valuable suggestions in this investigation.

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DISCUSSION

Dr. Raheja enquired in what way this needle differed from the one reported earlier by Mr. Farooque at Jullundur. Dr. Sen replied that the needle devised by him had a smaller hole which lowered evaporation of juice and that the puncturing needle was also bent at an angle so as to enable drawing of only one drop of juice. Mr. Girdhari Lal felt that harvest control in U.P. with the numerous small holdings was not a practicable proposition and involved many administrative difficulties. Dr. Sen replied that in Bihar it had been shown that over 40,000 acres could be surveyed in 7 days. Mr. C.N. Agarwala said that in Bihar, with the consent of the Varieties Advisory Committee, the factories had been allowed to get cane on maturity basis.

GENERAL

Mr. A. S. Srinivasa Murthy presented the following paper.

Paper

QUALITY CONTROL OF FERTILIZERS*

A. S. Srinivasa Murthy**

The Nizam Sugar Factory Limited, Shakarnagar, India

1,00,000 tons of nitrogen and 12,000 tons of phosphoric acid were used by Indian agriculture in 1953-54. 3,70,000 tons of nitrogen and 1,20,000 tons of phosphoric acid will be used in 1960-61. Yet there exists no control over the quality and marketing of these fertilizers.

The Nizam Sugar Factory annually spends Rs. 25 lacs on fertilizers for their own use and another Rs. 25 lacs to meet, in part, the fertilizer requirements of the 6,000 cane farmers who sell their cane to the factory. As such, they are vitally interested in the quality and conditions of marketing of fertilizers.

It has been observed from time to time that the quality of ground-nut cake, which is widely used, was variable. Some so-called mixed fertilizer samples received, had little or no nutrient value. The weight of the groundnut cake and others, in the bags was also not uniform.

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* The term "fertilizer" is used in this paper to include organic "manures" like the oil-cakes, bonemeal and other organic materials.

** Acknowledgment is due to Mr. M. Karamathullah Khan, Statistical Officer, for statistical analysis of the data.

The plantations department brought this to the notice of the management and insisted that fertilizers of good quality only should be purchased. In view of this, they decided in 1953, to stipulate in their purchase orders the quality (N_2 or P_2O_5 contents) and to make the payment of the full contracted price subject to the quality of the supplies conforming to specifications. Pursuant to this arrangement, over 1,600 consignments received so far, have been sampled and analysed according to the A.O.A.C. methods (I). This study has given valuable information about the large variability of the quality of fertilizers available. This is presented here as the subject is of great significance to all sugarcane cultivators, half of whose budget is made up of fertilizer costs.

As an illustration, data regarding groundnut cake are given here. Three types of groundnut cake are usually marketed. "Ghani" cake, obtained from small bullock crushers, is comparatively rich in oil and is in the form of big clods and is not used in any appreciable quantity as fertilizer. The second, and the most widely used type is "Expeller Cake" obtained from power oil expellers. It is in the form of thin flakes and a good sample is supposed to contain 7% total nitrogen. Data regarding the N_2 content of 662 consignments received over a 9 month period in 1953-54 from different suppliers are presented here. The data were statistically analysed and fitted to a normal distribution curve and it was found to be a good fit. The theoretical frequencies were computed for a normal distribution and are given in Table I. Cost per unit of nitrogen, of each class, taking Rs. 200 f.o.r. Shakarnagar, per ton as a standard price is also indicated in the Table.

TABLE I

FREQUENCY DISTRIBUTION OF THE TOTAL ORGANIC N_2% IN 662 SAMPLES OF EXPELLER GROUNDNUT CAKE

Total organic N_2% on air dry basis	Observed No. of samples in each class	Computed frequencies in each class when n=100	Calculated cost per unit of N_2 in Rs.
Less than 5	28	2.50	42 2 0
5.0—5.49	63	5.43	38 1 0
5.5—5.99	92	11.56	34 12 0
6.0—6.49	122	18.34	32 0 0
6.5—6.99	128	21.65	29 10 0
7.0—7.49	134	19.04	27 9 0
7.5—7.99	61	12.47	25 12 0
above 8	34	9.01	24 3 0

Range—4.97: Arithmetic mean—6.53 ;
Standard deviation—0.90536.

It is clear that nitrogen content, the main criterion of judging the quality of expeller cake varies within wide limits. Without proper protective clauses in the purchase contract the factory would be paying anything between Rs. 24/3- to Rs. 42/2/- per unit of nitrogen. At their standard rate of top dressing of 2 tons per acre, and without proper analysis, their cane crop would receive anything between 212 lbs. to 370 lbs. of nitrogen per acre. In the light of this study only 6.5% is now stipulated in the purchase orders and not 7% which is generally supposed to be normal for groundnut cake.

Another type of groundnut cake, marketed to a limited extent, is 'deoiled' groundnut cake. In a good specimen, the oil is completely removed and the product is a fine powder, easy to apply uniformly and easily decomposed in the field. The price is much higher than that of expeller cake (about Rs. 270 per ton). Nearly a hundred consignments were tested and it was found that while the total N_2 content was fairly uniform, many samples were heavily adulterated with other materials, perhaps sawdust or sand and the like ; and the specified N_2 content was made up by addition of ammonium sulphate whose cost per unit of nitrogen is less than half that of deoiled cake. The value of this deoiled cake lies in its high organic nitrogen content and such adulteration, notwithstanding the high total nitrogen, depresses the value.

The same variability in the N_2 content was also noticed in the case of other oilcakes, like safflower cake. Many consignments received were mixtures of groundnut and safflower ("kardi") cakes. It appears that it is a common practice to mix some safflower seed along with groundnut in the expellers. This is believed to reduce the value of the oilcake as a manure. The physical condition of the oilcake also is an important factor. In 1949-50, when groundnut cake was in short supply, castor cake was used. Some of the consignments contained big slabs of castor cake, which could not be used in the field, without powdering.

Data regarding the total P_2O_5 content of 110 consignments of double superphosphate received over a five month period in 1954 from the same manufacturers is given in Table II.

TABLE II

OBSERVED FREQUENCY DISTRIBUTION OF TOTAL P_2O_5 CONTENT IN 110 SAMPLES OF SUPERPHOSPHATE

Total P_2O_5	Observed frequencies in each class	
Below 12	3	
12 — 13.99	19	Range=9.62
14 — 15.99	24	Arithmetic mean=16.05
16 — 17.99	52	Standard deviation 1.95653
Above 18	12	Standard error 0.18654

Though the number of samples is not large, it clearly illustrates the large variation of quality of even manufactured fertilizers, made and supplied by the same firms.

In addition, several mixed fertilizers also were tested. A few samples sent by vendors doing business under impressive names contained only traces of plant nutrients. Another trial consignment of a fertilizer mixture contained the guaranteed 6.5% nitrogen, all in the form of ammonium sulphate, the rest of the mixture was some useless material, which appeared to be tamarind seed husk. While such undesirable practices are by no means common, it cannot be denied that such practices are prevalent in the trade and a gullible farmer will pay good money for nothing.

Almost as a rule there are no markings on the containers to indicate the name, composition, weight, etc. of the fertilizer and the maker's name, except on the products of some well-known manufacturers of inorganic fertilizers and mixtures and even they generally mention only the total nitrogen and total phosphoric acid contents and not the soluble nitrogen and available phosphoric acid contents. The proportion of the organic form of nitrogen is a very important consideration in judging the value of fertilizers for sugarcane. It has been established by the sugarcane research station of the Nizam Sugar Factory and also by the Bombay Government's Sugarcane Research Station at Padegaon (2) that 3/4 or at least 2/3 of the nitrogen applied to sugarcane should be in the organic form (as groundnut cake) to give good yields. Only inorganic nitrogen, as ammonium sulphate or a predominantly inorganic nitrogenous top dressing has proved detrimental. The Nizam Sugar Factory, the many factory plantations in the Bombay Deccan and others find it essential to supply most of the nitrogen in the organic forms.

Because of the resources and organisations at their disposal, the Nizam Sugar Factory and a few other purchasers can safeguard their interests to some extent. Barring these few, all the other purchasers are quite helpless in the matter. No doubt, the farmer can send a sample and have it analysed by the Agricultural Chemist. But this facility is totally inadequate, and in any case, it does not help the farmer because even if the fertilizer is deficient, the seller gives no guarantee and no claims can be made by the purchaser.

It is necessary that the maker should mark on the containers, the name, weight, chemical composition, including water soluble nutrient content etc. In the case of oilcake the expeller owners must be compelled to mark the name of the oilcake and if it is a mixture of 2 or more cakes, their names and proportions. These statements should have the force of a legal warranty and it should be open to the purchasers to make claims on the vendor whenever a deficiency is proved.

This can be possible only if necessary legislative and executive action is taken by the Government to regulate the quality and terms of marketing of fertilizers, as has been done in the case of other commodities. Adequate facilities should be provided to the farmer to get his purchases properly sampled and analysed by staff, specially charged with this work.

SUMMARY

The large variability in the quality of fertilizers has been established by studies undertaken by the Nizam Sugar Factory and is presented in this paper as this is a problem of vital interest, particularly to economic cane production, half the cost of which is made up by the fertilizer costs.

The need for control over quality of fertilizers and regularisation of trade practices to protect the purchaser is stressed.

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Dr. P. C. Raheja presented the following paper.

Paper

PHYSIOLOGICAL RESEARCHES IN RELATION TO AGRONOMY OF SUGARCANE IN INDIA

P. C. Raheja

Indian Agricultural Research Institute, New Delhi, India

INTRODUCTION

There are two distinct cane belts in India. The sub-tropical North has much larger area under cane than the tropical owing to its being in the monsoonic region where supplemental irrigation exists. The cane is planted in the months of February and March, depending upon the optimum temperatures for the germination of the crop. This season is usually dry. It is followed by a continuous hot dry spell till monsoon breaks in late June or early July. The germinated plants subsist either on conserved soil moisture or frequent irrigations. These conditions coincide with the developmental phase of the crop. The plant tillers and produces new shoots in proportion to the availability of soil moisture, nutrient status of the soil, available space and net assimilation rate in the photosynthesising leaves. A stage arrives when some limiting factor checks further development of the plant. If the soil moisture is adequate the plant after completing its formative growth, enters upon its grand growth stage. This phase of growth in the sub-tropical region coincides with the start of monsoon. High humidity coupled with ready availability of soil moisture and optimal temperatures result in high net assimilation rate in the crop. Even in the extremely northern area of the Peshawar valley, in West Pakistan, light showers raise up atmospheric humidity and bring down temperatures. This season lasts from July to September. It is during this period that stalk formation is the maximum and is almost completed.

The temperatures tend to decline early in October. A wide range of temperatures between day and night comes to exist which forms favourable environment for accumulation of sugars in the cane stalk instead of their being utilized for active growth. The crop approaches its maturity in December when cane crushing starts.

In the tropical belt, in the South, the climatic conditions are milder than those in the North. The cane is planted in two seasons. August-September planted cane keeps on the land for about 16-18 months. The February planted one is ready for harvest in 12 months. The August-September cane has more profuse tillering. The subsequent mortality of tillers is low. The hot weather does not put a limit on tillering of the crop. The grand growth starts with the onset of monsoon, which starts 15 days to a month earlier than in Northern India. Most of the soils in this region are heavy in nature and the crop, because of excessive growth, requires frequent irrigation. The water requirements, therefore, are quite high.

Physiological researches in both the regions have been extensively conducted and reported from a chain of sugarcane research stations set up by the Indian Council of Agricultural Research in 1932-33. These researches pertain to germination, tillering and growth of crop; its nutrition; culture of cane; water requirements ; quality ratio of cane at harvest; drought, water logging and frost resistance in cane. The work on those aspects has been summarised with a view to provide better understanding of the factors contributing to high production of cane in India.

GERMINATION

The germination is influenced by the size of seed piece, and stage of its maturity. Three budded setts give higher germination than two or single budded setts. Similarly unripe portions of cane are quick to germinate. Stale seed is less viable than fresh seed, cut the same day, for planting. In fact immediate planting of cane after harvesting is more beneficial than planting top or middle internodes (Venkatraman—1926. Singh—1942; Misra—1946). High glucose and high moisture percent in cane favourably influence germination. The critical point of moisture in cane for good germination is 50% of the water content in fresh cane (Khanna-1933 & 1934; Rege and Wagle—1939). Topping canes 4-6 weeks before planting and using rayungens as seed cane increases the establishment of shoots much larger in number than with normal seed (Mukherjee and Ram Kishan—1948). A bulk trial at Nellikupum has confirmed the beneficial effect of this practice (Jayaraman-1954). That soaking of seed pieces results in higher germination has been shown by several workers. The treatment which has proved to be the best consists of lime saturated solution in combination with magnesium sulphate (Khanna-1933 and 1934 ; Mathur-1941). The optimum pH for good germination and subsequent growth of cane is between 6.0 to 7.2

(Singh and Rao-1937). Various hydrogen ion concentrations indicated differential effect on the germination of sugarcane. There is a positive correlation between germinating energy and dry matter output by plants. It is maximum at 6.8 pH for 24 and 48 hours soaking. Ninety six hours, soaking decreased germination (Chakravarti and Rao-1935). Soaking of setts in dilute solutions of N.A.A. and M_nSO_4 markedly improves germination (Vijayasarthy, Narasimha and Ramanujam—1954).

Date of germination of plants materially influences the subsequent development. Earlier the germination greater is the tillering. Varieties show similar reduction in tiller number of the plants as germination is delayed (Agnihotri-1953).

Soil moisture and temperature both have been found to influence germination of cane. Temperatures above 55°F are conducive to good germination (Khanna-1933; Rege and Wagle-1939).

In Peshawar valley, West Pakistan, seed is normally clamped as a safeguard against recurring frosts to avoid injury to buds. The clamp is usually made air tight so that temperatures and humidity remain fairly high and quite conducive to initial sprouting of buds. The percentage germination exceeds 80% as against 40-50% for unclamped cane. This high initial stand makes considerable difference towards crop yield.

The practice of clamping seed cane is also common in Delhi State and S. Eastern Districts of the Punjab. The cane is not put in a clamp but is pitted in the soil in the month of February. It is taken out in late March or early April and then planted. The purpose of pitting is to carry out initial sprouting under more humid and equable temperature conditions. This seed gives higher germination compared to unpitted seed.

TILLERING

The tillering or underground branching of cane received considerable attention at the hands of Barber (1919). He established formula for each group or class of canes and for the various wild relatives of cane. He observed that *Saccharum Spontaneum* had the longest formula of all the related species. The extention of formula was less in *Saretha*, *Mungo* and *Pansahi* groups which appeared more akin to *S. Spontaneum* and farther removed from noble canes. The underground branching in *Sunnabile* and *Nargori* groups was restricted utmost to 'C' shoots and in noble canes more or less to 'B' shoots. It is, therefore, that Barber achieved success in interspecific crosses between *Saccharum Officianarum* and *Saccharum Spontaneum.* The hybrids had comparatively high tillering compared to the noble canes and that contributed to their tonnage very appreciably. Similar success was not achieved when he crossed canes of *Saccharum Officianarum* with canes of *Saccharum Barberi.* In Northern India where the growing crop has to contend against hot weather, immediately after germination, and tiller production is restricted by critical temperatures, inherent ability of canes to produce larger number of tillers is a valuable asset.

The hybrid seedlings show considerable variation in tillering. The ultimate survival of tillers forming canes depends upon the maximum number of tillers produced by various varieties. Early formed tillers have a greater chance of survival than late formed tillers and the contribution of the former to the ultimate tonnage is very great. The quality ratio of the crop is also determined by the early formed tillers. Late formed water shoots, particularly in Southern India, while they do not contribute appreciably towards the cane tonnage, distinctly lower the quality ratio of the crop (Rege and Sannabhadati-1942, Panje-1943 ; Raheja-1946).

The tillering in cane is interrelated to nitrogen dose applied to the crop. In Southern India doses beyond 300 lbs. nitrogen and in Northern India beyond 150 lbs. nitrogen per acre do not increase further tillering. Nitrogen doses, in fact, influence tillering much more than the growth in height of the crop. Application of farmyard manure or equal nitrogen basis is less effective than inorganic fertilizer nitrogen (Mathur and Haider-1940 ; Singh-1941 ; Rege and Sannabhadati-1944 and Singh-1950).

In early planted cane tillering is more than in the late planted cane. This fact has been recorded both in Northern and Southern India. Temperatures below 70°F definitely retarded tiller formation. Wider range between mean maximum and mean minimum temperatures in April, May and June conduced to larger tillering. Mean temperatures round about 90°F were very favourable for tillering in the months of May and June. But early onset of monsoon with consequent reduction in the range of temperatures promoted growth in height and cut short the period of tillering of the crop (Raheja-1948 and 1950).

Irrigation combined with nitrogen influences tillering beneficially much more than irrigation. Excessive irrigation retarded tillering in crop alone. Deficient irrigation lowers tiller production in various varieties. In North Bihar where soil retains high content of moisture application of irrigation depresses tillering. But together with 60 lbs. of nitrogen, by fractional application, the tillering is very much improved (Mathur and Haider-1940; Khanna-1950; Singh-1950).

Tillering in ratoon crop starts early and is more profuse than in plant cane. The number of surviving tillers depends upon the tiller number at the end of hot weather. Wider spacing decidedly reduces the mortality of tillers. Degree of variability in tillering is less high than the degree of variability in stalk weight. Varieties exhibit significant linear relationship between tillering and weight per plant. Tillers of various orders of emergence indicate high consistency in their homogeneity in characters of mean weight of stalk, length of stalk and mean weight per cm. stalk length. Partial correlations amongst the factors of main stalk, mean clump weight and tillering per clump indicated that increased stalk length is complementary factor in tillering in increasing the clump weight, the contribution of stalk length being much less than of number of stalks in the increase in weight of the clump. There was significant negative association between tillering and sucrose percent in juice. This association became weaker as the cane matured with the fall of temperature and the decrease in the hydration of tissues. This interrelationship of various characters to tillering (No. of canes in the clump) worked out as follows :—

TABLE I

INTERRELATIONSHIP AMONGST TILLERING, PLANT WEIGHT, LENGTH OF STALK AND QUALITY RATIO IRRESPECTIVE OF TREATMENTS TO CROP

No. of canes per clump	Mean length of stalk (cm.)	Weight of clump (lb.)	Sucrose in Juice %	Brix %	Purity
3	216.9	5.08	15.88	18.65	86.53
4	213.4	5.90	15.73	18.19	86.50
5	209.9	6.71	15.59	18.02	86.48
6	206.3	7.52	15.44	17.86	86.46
7	202.3	8.33	15.29	17.69	86.43

Briefly the above statement indicated that with the increase in tillering and consequent increase in plant weight, there is tendency for the length of millable stalks, sucrose, brix and purity to decrease. The purity is affected to a much less extent compared to sucrose or brix values of the crop (Raheja and Misra-1954, Raheja and Singh-1954).

GROWTH IN HEIGHT

At all the Sugarcane Research Stations in the country growth in height observations are recorded as a routine practice to select varieties suitable for various regions. Barber (1915 and 1918) recorded growth observations on indigenous cane varieties to study their different characters for classifying them into ecotypes. The characters of length of stripped cane, number of joints, average length of joints, mean thickness of cane and cane module were later used to distinguish between ecotypes of *Saretha* and *Sunnabile* group of canes. The much higher value of cane module in *Saretha* group indicated that, as a class, these canes were thinner and longer than those of *Sunnabile* varieties.

Khanna (1930) conducted a comparative study of *Katha*, Co. 205 and Co. 285 with respect to number and rapidity of development of roots and their functioning period, shoot roots, and shoot development. It was observed that seedling canes Co. 205 and Co. 285 surpassed *Katha* in shoot weighments. Venkatraman and Hussainy (1933) observed that weighment of shoots at regular intervals is a good index of the performance of new varieties in comparison to local standard.

Rege and Sannabhadti (1944) recorded growth in height of crop with nitrogen alone and combined application of nitrogen and phosphorus. In 1937-38 season, the beneficial effect of phosphate was restricted to the tillering phase. The differences in total height and height of millable stalk were quite pronounced up to August and later the growth tended to slow down and conduced to early maturity. In 1938-39, the basal dose of phosphate in relation to tillering and growth made small difference. This was due to high sufficiency of phosphate in the soil. These authors (1944) also reported results of nitrogen fertilization on growth of the crop and found that relative growth rate, calculated from production of total dry matter was practically the same in the nitrogen dose treatments of 600, 450, 300 and 150 lbs. doses. But the dose of 75 lbs. N showed lesser relative growth rate than others. After August in treatments of 75 and 150 lbs. N the growth almost ceased and in 300 lbs. it continued a month later, while in 450 and 600 lbs. no cessation of growth occurred in the tropical conditions of Padegaon.

Exponential growth curves were fitted to the data for varieties and the parameter 'A' values were correlated with the cane yield and parameter 'b' with the sucrose content in juice. In the medium early series, the results obtained were as under :—

TABLE II

CORRELATION COEFFICIENTS

Parameter A = A ; Mean yield per acre in Mds = B ; Parameter 'b' = C ; Mean sucrose percentage in juice = D

	Growth constants, yield and sucrose data											
Varieties	1941-42				1942-43				1943-44			
	A	B	C	D	A	B	C	D	A	B	C	D
Co 312	12.34	767	0.01435	10.23	5.68	552	0.01284	10.99	12.55	806	0.01034	12.05
Co 427	11.10	637	0.01556	11.35	2.50	430	0.01653	12.35	17.53	741	0.01076	13.02
Co 549	9.42	453	0.01544	12.06	2.03	400	0.01829	12.61	9.74	641	0.01104	14.37
Co 299	8.63	499	0.01595	12.32	1.82	432	0.01842	12.66	9.60	596	0.01049	13.20
Co 313	7.53	656	0.01643	11.96	2.35	449	0.01786	13.11	8.69	716	0.01247	13.34
Co 281	6.44	375	0.01785	13.31	1.97	321	0.01848	13.56	6.68	574	0.01345	14.53
Coefficient of correlation	+0.326		+0.926		+0.818		+0.915		+0.556		+0.711	
Significant at			P=0.01		P=0.05		P=0.01		...		P=0.10	

The value of Correlation Coefficient between the mean yield of varieties and their initial rapidity of growth values (Parameter A) was low in 1941-42; it was significant at 5 percent level in the year 1942-43 and moderate in the crop season 1943-44 but not significant even at 10 percent level of significance. Correlation Coefficient between the relative growth rates (Parameter 'b') of the varieties and their mean sucrose percentage in juice were significant in all the three years. In the first two seasons the values were very high while in the third season, *i.e.*, in 1943-44, it was significant at 10 percent level only. The results indicate that in early maturing varieties the yield is influenced by the initial rapidity of growth and the accumulation of sugar is closely bound up with the relative rates of growth of the varieties.

The same type of correlations was worked out for the data obtained on varieties in the mid-season trial.

TABLE III

VALUES OF PARAMETER A AND ACRE YIELDS
PARAMETER A VALUE=A ; MEAN YIELD PER ACRE IN MDS.=B

Varieties	1941-42 Plant crop		1942-43 Plant crop		1942-43 Ratoon crop		1943-44 Plant crop	
	A	B	A	B	A	B	A	B
Co. 331	11.52	1071	7.56	339	5.00	1012	10.13	368
Co. 312	9.98	944	5.83	457	4.19	714	11.06	515
Co. 290 (St.)	9.36	743	6.91	375	5.96	664	8.03	368
Co. 438	8.34	838	5.46	429	3.04	529	7.75	408
Co. 451	7.62	916	6.55	272	0.68	644	8.96	317
Co. 419	6.30	911	4.53	182	3.18	709	8.46	389
Co. 534	4.34	756	3.76	272	1.25	534	2.12	267
Coefficient of correlation	+0.41		+0.382		+0.534		+0.817 (P=0.05)	

The values of correlation coefficients worked out between parameter A values and the mean yield values in all cases gave positive correlations. The value was significant for one season out of four. In the case of medium-early varieties trial, a similar position had been noticed which indicates that the initial rapidity of growth, although influencing the yield, is not the major factor determining the yields of the varieties.

Correlation coefficients, worked out between parameter 'b' values and the sucrose content for the varieties for all the seasons, whether for plant or ratoon crops, were significant. From this it is obvious that relative growth rate values have much to do with the accumulation of sugar in juice.

Studies in Peshawar in Pakistan indicated that the differences in mean monthly growth, cumulative growth in length and mean daily growth were small due to basal manuring. Similarly no consistency could be observed in the results of initial rapidity of growth and relative growth rates in height of crop in different years. But when top dressings of ammonium sulphate were given, the results of cumulative growth in length indicated that absolute growth in height increased with the increase in dose of nitrogen. In two out of 4 years the differences were significant. The initial rapidity of growth (Parameter A) and relative growth rate (Parameter 'b') considered together for all the years indicated small differences for varieties in nitrogen treatments (Raheja 1951).

Soil moisture as well as humidity of the air influences very considerably the growth of sugarcane crop. Rege *et al* (1943) observed that humidity plays an important role in plant development. Study of six years data showed that the correlations of growth with humidity were significant at 10% level of significance for 5 years in case of Pundia and for three years in case of POJ 2878. This indicated that Pundia was more susceptible to changes in humidity than POJ 2878. Over irrigation with 130 inches of water depressed the growth of the crop in the later stages due to leaching down of nitrates otherwise increasing doses of water in the other three treatments of 70, 95 and 100 inches, beneficially influenced the growth of the crop. Application of 70 inches of water was short of requirements in the early stages of growth.

The data on cumulative growth in length, mean daily growth rate and exponential height growth curves of several varieties in different experiments conducted in the three years 1940-41, 1941-42 and 1942-43 indicated that, besides the environmental factor of temperature and humidity, irrigation supply also conditioned cumulative growth in length of the crop. Maximum growth accumulation was shown by the weekly interval irrigation treatment which quickened early growth and mean daily growth rate of the crop. Both these tended to augment the yield. The treatment of critical soil moisture limit for application of irrigation in majority of the experiments conduced to greater accumulation of the commercial cane sugar and high relative growth rate of the crop.

Asana (1950) working on growth of Co. 313 in North Bihar observed that the monsoon season growth suffered during protracted drought periods which was indicated by depression in the rates of assimilation and leaf growth. Under water logged conditions the rate of uptake of nitrogen decreased and in consequence leaf growth suffered. Based on these observations Asana suggested that varieties suitable to drought and water logging conditions may be selected on the basis of rates of assimilation and leaf growth of cane crop in North Bihar.

RESPIRATION AND ASSIMILATION

Respiration studies conducted in North Bihar, where crop entirely subsists on conserved soil moisture during the hot weather, indicated that seasons have a marked influence on the respiratory process of sugarcane plant. Also the varieties respond differently to the same weather conditions. Under conditions of stress, varieties, according to their biological resistance, tend to meet the environment usually by cutting down their respiration rate (Khanna and Raheja-1938 and 1948). But the stress proving beyond the biological resistance of the varieties affects their development and growth. Accordingly the varieties studied in the two seasons could be classified into three groups :—

(*i*) Xerophytic or drought resistant,

(*ii*) Semi-xerophytic or drought escaping, and

(*iii*) Meso-phytic or least drought resistant.

The interaction effect between the varieties and the periods was significant. These data are given in Table IV.

TABLE IV

INTERACTION EFFECT BETWEEN VARIETIES AND THE PERIODS

Varieties	Periods of working I	II	III	IV
Co. 299	1.116	0.772	0.811	0.917
Co. 313	0.611	0.731	0.611	0.603
Co. 213	1.578	0.793	0.619	0.419
Co. 356	1.150	0.874	0.976	0.499
Co. 331	0.821	0.873	0.726	0.621

S.E.=±0.2345 C.D. at 5 percent level=±0.2323

Co. 213 variety indicated the maximum depression and the next worst was Co. 356. On the contrary varieties Co. 313 and Co. 331 cut down respiration to lesser extent and did not show significant differences from period to period.

In North Bihar, rivers, when in spate, flood low lying areas. It is only the cane crop which can withstand partial submergence. Investigations in respiration of the crop under partial submergence were conducted. It was generally observed that after some days of partial submergence 12 varieties, on the whole, showed higher rate of respiration in foliage, cane and root than normal material standing unsubmerged. The differences were statistically significant in the case of cane and root respiration. Respiration experiments on seven varieties of sugarcane under controlled conditions indicated specific differences in curves of foliage respiration. According to the shape of the curves the varieties studied could be classed as under :

Tolerants—Co. 331, Co. 328, and Co. 285.
Semi-tolerants—Co. 281 and Co. 313.
Susceptibles—Co. 213 and Co. 210.

The ratoon crop of Co. 213 was observed to be more tolerant than the plant crop. The course of respiration exhibited was widely different in the two cases. (Khanna & Raheja—1948). Later studies have shown a drop of 30% to occur in polarisation; but invert sugars, total colloids, gums, pectins, non-protein nitrogen and ash increased on water logging (Khanna and Chacravarty—1949).

In pots, plants were raised on different media to study the respiration response to nitrogen, phosphorus, potash and minor elements. The respiratory activity studies were carried out both on normal and starved plants. Application of nitrogen reduced the rate of respiration. The rate of respiration was lowest when it was applied in combination with all other elements. The effect of potash was just the opposite to that of nitrogen. It enhanced the rate of respiration unless it was present in combination with NP. Phosphorus alone increased the rate of metabolism. In combination with nitrogen it was very effective in reducing the rate of respiration but without nitrogen and in combination with potash it kept up a higher rate of respiration. Minor elements when applied alone behaved like potash. These in combination with nitrogen, phosphorus or potash reduced the respiration rate. Potash has been shown as the first limiting factor as it is the earliest to show adverse effect on the respiratory process and it maintains its antagonism so long it does not combine together with nitrogen and phosphorus (Khanna and Raheja—1948).

Asana (1948) determined assimilation rates by the Sach's half-leaf method of few sugarcane varieties in North Bihar. The differences in the carbohydrate contents of the morning and afternoon samples indicated that in net assimilation rates there was considerable difference from variety to variety.

Rege and Sannabhadti (1943) determined rate the of photosynthesis in sugar-cane leaf by the Ganong's punch method. The results are summarised in Table V.

TABLE V

RATE OF PHOTOSYNTHESIS

(Percent increase in weight at 3-0 P.M. over samples taken at 8-0 A.M. by Ganong's punch method)

(Average of 10 randomly selected plants)

Treatment	Percent increase in weight Mid-May	Mid-August	Mid-October
1937-38			
A. 300 N+No P_2O_5	11.9	7.1	...
B. 300 N+100 P_2O_5	16.7	13.7	...
1938-39			
A. 300 N+No P_2O_5	5.7	6.3	11.3
B. 300 N+100 P_2O_5	5.1	8.5	9.0
C. NoN+100 P_2O_5	26.9	9.4	2.2

The effectiveness of phosphorus in increasing the rate of assimilation was manifested in 1937-38 in mid-May and mid-August. In the second season, it was again evident except in mid-May for treatment B, although it enormously showed higher value in treatment C. There was a fall in assimilation rate in mid-October for both the treatments B and C respectively, compared to treatment A which consisted of nitrogen alone.

Dutt and Narasimhan (1951) studied the occurrence of starch in various parts of bottom and top internodes of *Saccharum officinarum* and other species of *Saccharum* and *Erianthus*. Generally they observed that the internodal portion in *S. officinarum* was free of starch but related species contained fair to abundant amount of starch. These results have been discussed from the point of view of evolution of *S. officinarum* from *S. robustum* and *Sclerostachya*.

Verma (1954) reported that carbohydrate synthesis is high in the pretillering phase after which it remains more or less constant in leaf and leaf sheath. But in the stem the sugar accumulation begins to increase rapidly in the senescent phase of the crop. The high sucrose content is maintained for about 2 months. The carbohydrate/nitrogen ratio constantly went up as there occurred more and more of sugar accumulation in the plant.

Application of 0.2% acid equivalent spray of 2, 4-D, *i.e.*, 2 lbs. in 100 gallons raised the sucrose in juice for 2-3 days after spraying. This difference was not maintained after that period (Mathur—1950).

WATER BALANCE AND DROUGHT RESISTANCE

The problem of water relations of sugarcane plant has been investigated from various points of view in India. But the major emphasis have been on water requirements, irrigation control and drought resistance in different varieties of sugarcane. Leather (1911) worked out water requirements of sugarcane and noticed that manuring of the crop in pots had a beneficial effect on the economy of water expenditure by the crop. Subsequently Singh and colleagues (1935) took several varieties of cane and determined their relative efficiency of water requirements. They observed that thick canes with large transpiring surface had high water requirements ; while cross bred hybrids possessing high yielding power had less water requirements. They noticed a linear relationship between dry matter and water requirements of varieties of sugarcane. The water requirements of sugarcane were estimated at 45.23 acre inches (Singh *et al*-1935).

In North Bihar hot weather is the most critical period for cane growth as the crop has to subsist on conserved soil moisture. Field studies on relative water requirements of varieties belonging to three different groups, namely, drought enduring, drought escaping and mesophytic types were conducted during the hot weather. These varieties were found to differ widely in their relative efficiency of water requirements. A linear proportionality was observed between the relative water requirements and the dry matter produced by them. A high negative coefficient of correlation was observed between the assimilation capacity of plants and their water requirements. Capacity of varieties to resist drought did not necessarily mean an economical use of water by them. Degree of development of transpiring surface also did not exhibit significant relationship to the relative water requirements of varieties (Khanna and Raheja-1938).

Rege *et al* (1943) reported results of water requirement studies conducted over a period of three years. The treatments included for study were 70, 95, 120 and 130 inches of total water including effective rainfull. The rainfall received in three successive years was 17.94, 21.01 and 18.36 inches which was deducted from each of the treatments. Evapo-transpiration ratios were worked out for the two varieties Pundia and POJ 2878. These data are summarised in Table VI.

TABLE VI

EVAPO-TRANSPIRATION RATIOS

Treatment	Total received in irrigation	Total rainfall	Total water received by the crop	Total water utilized both in transpiration and evaporation per acre	Evapo-transpiration ratio		Evapo-transpiration ratio (Average of 3 yrs.	
					POJ2878	Pundis	POJ287	Pundia
1933-34								
70 in.	52.06	17.94	70	70.9	702	668	...	...
95 in.	77.06	17.94	95	68.8	755	615	...	...
130 in.	112.06	17.94	130	73.4	904	720	...	...
1934-35								
70 in.	48.99	21.01	70	56.2	828	1003	859	868
5 in.	72.99	21.01	95	60.9	960	1080	901	876
120 in.	98.99	21.01	120	62.9	943	1637	*1072	1427
130 in.	108.99	21.01	130	55.9	914	1037	1001	1027
1935-36								
70 in.	57.64	18.36	70	72.5	1046	939	...	...
95 in.	76.64	18.36	95	78.5	1017	933	...	...
120 in.	101.64	18.36	120	90.4	1072	1186	...	...
130 in.	11.64	18.36	130	84.4	1184	1325	...	...

*The figure is average of two years.

Obviously the evapo-transpiration ratios are dependent upon dry matter production. The wide fluctuations in ratios are explained on the basis of climatic factors, and production capacity of the two varieties. The evapo-transpiration decreased with 130 inches of water as the production per unit of water decreased in this treatment which is explained on the basis of loss of nitrates from the soil. The actual consumption of water averaged about 70 acre inches which is the minimum requirement. But 95 inches dose almost balanced the loss of water during the various intervals and was independent of the rainfall. When a manurial dose of 150 lbs. was applied, 120 inches of water appeared to be the optimum requirement in Deccan canal tract. Further experiments conducted at factory estates confirmed that 12 months crop requires about 115 acre inches of water (Rege and Rao-1954).

In Peshawar sugarcane is an irrigated crop. Due to peculiar climatic conditions, frequently the ripening of the crop suffers and judicious use of water is helpful in inducing early maturity of the crop. In field tests a linear proportionality observed between the weight of the crop and the relative water requirements of the varieties was found to be significant. Varieties on the average required a minimum of 40 acre inches of water for optimum crop production.

The critical moisture stage irrigation treatment lowered the yield of cane in all the experiments, but there was a corresponding increase in C.C.S. percent values of the crop. In two out of three trials this increase was more than sufficient to compensate for the decrease in yield. In fact, in two trials there was an extra return of sugar per acre with the critical moisture stage irrigation application compared to even liberal irrigation treatment (Raheja-1944).

Parthasarathy *et al* (1951) observed that tillering of the crop increased with longer intervals of irrigation. Frequent irrigations increased the cumulative growth in height. Crop under longer interval of irrigation arrowed sparsely and, therefore, continued its growth beyond December. On the other hand arrowed canes stopped cane formation by December.

The quality of cane also improves under longer intervals of irrigation. In the Deltas of Andhra State, the total water requirements of the crop is between 55 to 60 acre inches. Parthasarathy and Vaidyanathan (1954) further reported that the fluctuation in juice quality with heavy nitrogenous manuring were much greater with heavy than with light irrigations. The interaction between irrigation and nitrogenous manuring was significant. Singh and Gill (1954) similarly noticed that higher doses of nitrogen depressed the sucrose content significantly while different six moisture levels did not affect the juice quality so much. The interaction between nitrogen and soil moisture was not significant.

FROST TOLERANCE

The cane crop suffers in three ways from frost. Firstly, the tips of leaves are killed and guard cells of stomato are rendered inactive over the entire surface of the leaves; secondly, the buds and root primordia are injured ; and thirdly, there occurs deterioration in juice quality of the crop. Varieties widely differ in relative injury by the action of frost in all the three respects (Lander and Narain-1932). Observations recorded in 1944 when the minimum thermometer recorded 21°F and grass thermometer 19°F, the foliage susceptibility was indicated as follows (Raheja-1945):—

TABLE VII

FOLIAGE SUSCEPTIBILITY TO FROST INJURY

Plant crop				Ratoon crop			
Varieties	Green leaf inches	Dry leaf inches	Ratio of Green/Dry leaf	Varieties	Green leaf inches	Dry leaf inches	Ratio of Green/Dry leaf
Co. 290	2.15	34.86	1 : 16.2	Co. 312	4.92	26.72	1 : 5.43
Co. 313	9.54	25.11	1 : 2.63	Co. 313	9.05	28.76	1 : 3.17
Co. 396	8.84	22.93	1 : 2.59	Co. 281	7.50	33.76	1 : 4.51
Co. 446	6.86	29.95	1 : 4.37	Co. 299	5.41	25.33	1 : 4.68
Co. 527	18.70	23.52	1 : 1.26	Co. 427	10.86	34.22	1 : 3.15
Co. K.31	4.14	29.83	1 : 7.20	Co. 549	7.60	21.78	1 : 2.87

From the frost injury point of view, variety Co. 527 suffered the least damage, moderate damage occurred in varieties Co. 313, Co. 427, and Co. 549, high damage occurred in varieties Co. 446, Co. 281 and Co. 299 and very high injury was done to varieties Co. 290, Co. K. 31 and Co 312. Comparatively, varieties having lower sucrose content suffered more frost injury than those containing high sucrose in cane.

On the basis of cane sampling bud mortality was calculated of a number of varieties under trial. The results of these observations are summarised in Table VIII.

TABLE VIII

PERCENT BUD MORTALITY IN VARIETIES

Degree of bud injury	50-60	60-70	70-80	80-90	90-100
Varieties	Co. 205 Co. 402 Co. 454	Co. 420	Co. 454 Co. 423	Co. 290, Co. 331, Co. 485, Co. 541, Co. 542, Co. 548, Co. 549	Co. 534 Co. 401 Co. 543 Co. 453

The frost in 1941-42 was so severe at Peshawar that every variety had over 50% of the buds damaged. Varieties highly susceptible to bud injury were far more than with low susceptibility (Raheja-1942). Singh (1950) observed that old ratoons and rainfed crop sustained heavy damage due to frost in buds and growing plants. Underground buds remain unaffected and stubbles can be used as planting material very safely.

In order to avoid injury to buds the practice of clamping the seed cane is very common in the frosty regions of India. High humidity coupled with above normal temperatures in the clamp stimulate bud growth.

The reduction in leaf area tends to influence adversely the rate of photosynthesis and translocation of sucrose into the stalk. In frost regions maximum accumulation of sugar takes place upto December. Later on frosts usually cause deterioration in juice quality by inversion of sucrose into glucose and fractose (Khanna and Raheja-1943).

Observations recorded on titratable acidity on a number of varieties, indicated that acidity showed a slight rise immediately after the cold wave in all the varieties but effect was short lived. Generally the ratoon crop had higher acidity in juice than plant crop.

NUTRIENT UPTAKE

Rege *et al* (1945 and 1944) have studied the uptake of N, P, K and Ca. The uptake has been studied from black cotton soil for above ground parts only. There was a progressive fall in the nutrient uptake from April to next January.

Taking the figure 100 as the base for April, the figures for January showed nitrogen uptake 25%, phosphate 45%, potash and calcium 68%. The production of dry matter was much more per unit of nitrogen than for other nutrients. The next in importance was phosphate. The differentiation in the percentage uptake of nitrogen amongst the treatments of 75, 150, 300, 450 and 600 lbs. N per acre was evident only in the later stages of grand growth period and at the maturity stage. The uptake of other nutrients remained almost unaffected by various levels of nitrogen. This created conditions of unbalanced nutrition resulting in continued growth and low maturity for higher doses of 450 and 600 lbs. N. Application of 100 lbs. P_2O_5 did not correct this unbalance. The total uptake of nutrients at various stages is given in Table IX.

These data indicate that uptake of nutrients is not equal. The uptake of potash is the maximum, nitrogen and calcium in moderate quantities and phosphate in least amount. With the age of the plant the nutrient uptake varied but not in the same degree of each nutrient. However, the major uptake occurred within the grand growth period. Application of N and P accelerated the uptake of all the constituents in the early stages. Phosphate was found to exert a great influence on the uptake of potash. In early maturing varieties like POJ 2878 in Bombay Deccan doses upto 450 lbs. N could be dressed without deteriment to the quality of juice but not so with late varieties. Application of phosphate improved both the quality of juice and cane tonnage (Rege and Sannabhadti-1941). Rege and Divekar (1954) observed that Boron spraying helped in early maturity of cane.

At Shahjehanpur in Northern India the nitrogen content of leaves was higher under different manurial treatments in the month of May when the plants were actively growing and tillering. Thereafter the nitrogen content was reduced successively with the aging of the crop. The leaves from unmanured plots early in life showed low nitrogen status. The fall in nitrogen content of leaves of the crop in the manured plots was gradual and far more prolonged than in the leaves from unmanured plots. The nitrogen content of leaves was high when 5 irrigations were given compared to 2 irrigations (Verma-1951).

Preliminary experiments conducted at Shajehanpur have indicated that spraying of dilute solutions of ammonium sulphate and sodium nitrate increases the yield of cane. Potassium phosphate had similar effect on cane crop (Verma-1954). Farooque (1954) applied 5% solutions spraying at the rate of 20 lbs. P_2O_5 acre and observed significant increase in P_2O_5 content in leaves than application of 20 lbs. P_2O_5 to soil. There was an unmistakable trend in higher uptake of nitrogen and potash under spray application of phosphate.

Studying metabolic characters of different growth phases of sugarcane, Verma (1954) observed that protein synthesis attained its maximum during the tillering stage after which it gradually declined. During the maturation stage all the nitrogen was in the form of crystalloid nitrogen. Observations of Divekar (1954) have shown that Co. 419 takes more of nitrogen and less of phosphoru compared to the uptake of these nutrients by Co. 475, which is said o explain the early maturity of the latter variety.

TABLE IX

UPTAKE OF NUTRIENTS PER ACRE IN. LBS. 1935-36

Treatment and Variety	Mid-May				Before earthing				Optimum				% of nitrogen utilized
	N	P_2O_3	K_2O	CaO	N	P_2O_3	K_2O	CaO	N	P_2O_5	K_2O	CaO	
POJ 2878 75 lbs. N	31.9	10.1	68.3	19.4	33.1	12.1	99.2	15.8	87.7	57.1	365.0	75.2	116.9
150 lbs. N	42.4	13.4	83.5	16.7	60.2	18.5	197.9	23.2	123.3	85.7	442.2	89.4	82.2
300 lbs. N	32.6	8.2	82.0	16.7	57.4	9.5	137.1	25.2	227.2	121.5	580.9	177.3	75.7
450 lbs. N	50.9	9.0	98.4	15.0	92.3	13.8	199.3	26.2	215.7	109.5	581.8	185.5	47.9
600 lbs. N	42.3	11.0	78.5	15.7	77.3	21.5	217.5	23.0	213.0	112.8	697.1	119.4	35.5
Pundia 75 lbs. N	25.7	8.4	58.0	10.6	34.0	9.5	102.5	15.1	79.7	71.2	364.1	93.6	106.3
150 lbs. N	24.7	10.6	62.5	5.2	47.9	10.4	112.3	16.2	90.1	80.3	397.6	88.6	60.1
300 lbs. N	27.7	9.1	59.9	10.1	31.9	12.5	104.6	18.0	151.2	114.3	531.9	134.3	56.4
450 lbs. N	26.9	7.2	55.8	9.3	49.6	21.2	93.0	39.7	121.9	100.9	570.0	121.6	27.1
600 lbs. N	22.7	6.3	52.1	10.3	29.2	17.1	92.2	20.4	132.8	89.3	408.1	113.5	22.1

LODGING

Studies carried out in Bihar (Khanna-1938, 1940) showed that lodging in sugarcane is a root phenomenon. The type of underground branching is somewhat responsible for the lodging habit of a variety. Observations recorded at I.A.R.I., New Delhi, have shown that application of high doses of nitrogen conduce to greater lodging of cane crop. Deep cultivation favoured lodging. Lodging reduced the height and girth of main shoot significantly. The angle of bent did not influence the sucrose content in cane. Lodged clumps, in general, had larger number of tillers than the unlodged canes. Application of phosphate reduced the extent of lodging. Both the extraction percent and sucrose content decreased by lodging of canes.

In India the practice of earthing up canes has become common. But earthing up is not so helpful in preventing lodging when the crop exceeds 25 tons per acre. Under such conditions a system of propping has been developed and is useful. In the coastal regions of Madras and Andhra States individual clumps are wrapped round bamboos, about 4000 to 8000 bamboos being used per acre for the purpose. To reduce this heavy cost, Parthasarathy and Reddy (1951) have developed a trash-twist method of tying canes. Two twists, one in August-September and the second two months later at heights of 4 ft. and 6 ft. are adequate to prop the canes. The method is becoming popular in the area concerned.

RESUME

A review of work done in India on the physiology of sugarcane crop in relation to its agronomy has been presented in the preceding text. The aspects of cane physiology treated in this review are germination, tillering, growth in height, respiration and assimilation, water balance and drought resistance, frost tolerance, nutrient uptake and lodging in cane. Relevant data from important publications is given to show how physiological studies are helpful in improving the technique of cane culture and better understanding of the problems of cane agronomy.

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DISCUSSION

Mr. Parthasarathy remarked that some of the statements made about lodging of canes in South India appeared to be inaccurate. Dr. Venkatraman thought loding of canes as also their recovery from the effects of lodging were mainly a varietal feature. Dr. Evans opined that there was no difference in juice quality between lodged and unlodged canes after the latter had come up again. Mr. Purnanand felt that there was no variety which was fully resistant to frost and varieties only showed certain degrees of resistance to frost. Dr. Raheja agreed that there was only a range of relative susceptibility or resistance to frost among different varieties and that the angle of bend in lodging was very important.

In the absence of the author, the following paper was taken as read.

Paper

THE ANALYSIS OF SUGARCANE EXPERIMENTS

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I THEORY

INTRODUCTION

The statistical technique applied to the analyses of agricultural experiments has been preferably aimed to annual crops, hence a great part of the experiments on sugarcane have been analysed following those rules. However, it is natural to think that the method of analysing the trials on a plant producing two or more crops differ a little from the classical. It is our intention, in this study, to develop some ideas on this aspect, which will allow us to lead to a more adequate analysis. We also present the example of a trial of 12 varieties that was continued for two crops; plant and first ratoon.

The statistical analysis submitted corresponds to a randomized blocks design, which, as well known, consists in situating all treatments at random within each replication.

MATHEMATICAL MODEL

All the statistical analyses of experimental designs form part of a mathematical model, which generally represents the observed yield as a linear function of the different factors considered as influential (4).

Anderson and Bancroft (1) and Pearce (5) indicate the advantage of considering the following mathematical model for perennial crops :

$$y_{ijk} = u + b_i + t_j + e''_{ij} + a_k + (ta)_{jk} + e'_{ijk} \quad \ldots\ldots (i)$$

where y_{ijk} is the yield (or any other characteristic) corresponding to the plot situated in block i to which treatment j was applied during season k, u is a general mean with respect to which the other effects are measured, b_i is the effect of block i, t_j is the effect of treatment j, a_k is the effect of season k, $(ta)_{jk}$ is the interaction of treatment j with season k, e''_{ij} and e'_{ijk} represent errors and are random variates with variances σ_2^2 and σ_1^2 respectively.

ANALYSIS

The mathematical model described corresponds to a 'Split Plot Design'. In this, the largest plot, to which one treatment corresponds, is ideally divided into several sub-plots to contain the different years or seasons into which an experiment is extended. In practice it is a simple Randomized Blocks Design which is continued for several years or seasons.

Let us consider : $i = 1, 2, \ldots r$; $j = 1, 2, \ldots p$; $k = 1, 2, \ldots q$; that is, an experiment with r replications, p treatments and q years.

Let us call R_{jk} the mean yield of variety j in season k. It is equal to the average of the yields obtained in each of the replications during that season.

$$R_{jk} = \frac{\sum_{i=1}^{r} y_{ijk}}{r} \quad \ldots\ldots (ii)$$

The yield of variety j through the q seasons or years, R_j is the sum of the mean yields obtained in each of those seasons :

$$R_j = \sum_{k=1}^{q} R_{jk} \quad \ldots\ldots (iii)$$

However, the total yield R_j is not a very good index to value the goodness of treatment j. Two different treatments, j and j', may have the same total yield, but one can be more convenient than the other. In order to explain this point better, let us consider the case of two sugarcane varieties yielding 100 Ton/Ha. in two crops, but the first one gives 80 Ton/Ha. in cane plant and 20 Ton/Ha. in ratoon, and the second one gives 50 Ton/Ha. in both crops. The cane planter would prefer one of the two and would never consider them equal.

Let us take I_j as the index to value treatment j and consider it :

$$I_j = \sum_{k=1}^{q} a_k R_{jk} \qquad \ldots\ldots (iv)$$

a_k is the coefficient with which the yield of season k is weighed. Coefficients a_k may be determined following a convenient judgement.

The object of all experiments is to establish a comparison between the treatments, and the analysis will serve to distinguish one treatment as equal, better or worse than any other. In our case, the problem is that once I_1, I_2, I_3,.... I_p are determined, we may discriminate them. Therefore, we need to know the value of the variance of I_j ; which, according to the mathematical model, is :

$$V(I_j) = \frac{\left(\sum_{k=1}^{q} a_k\right)^2 \sigma_2^2 + \left(\sum_{k=1}^{q} a_k^2\right) \sigma_1^2}{r} \qquad \ldots\ldots (v)$$

The values of σ_2^2 and σ_1^2 are estimated using the analysis of variance of Table I, which is calculated with the yield data obtained.

We have the following estimates :

$$\hat{\sigma}_1^2 = E_s \qquad \ldots\ldots (vi)$$

$$\hat{\sigma}_2^2 = \frac{E_p - E_s}{q} \qquad \ldots\ldots (vii)$$

which may substituted in expression (v)

TABLE I

ANALYSIS OF VARIANCE

Source of variation	Degrees of freedom	Mean square	Expected mean square
Blocks	$r-1$	B	
Treatments	$p-1$	T	
Error (1)	$(r-1)(p-1)$	E_p	$\sigma_1^2 + q\sigma_2^2$
Seasons	$q-1$	C	
Treatments x Seasons	$(p-1)(q-1)$	TC	
Error (2)	$p(r-1)(q-1)$	E_s	σ_1^2
Total	$rpq-1$		

The appropriate number of degrees of freedom for $V(I_j)$ is comprised between $(r-1)$ $(p-1)$ and $p(r-1)$ $(q-1)$. That number may be considered equal to $(r-1)$ $(p-1)$ for the significance tests without surely causing important differences.

The comparison of two treatments whatsoever taken at random j and j' may be made through Student's t test

$$t = \frac{I_j - I_j'}{\sqrt{2V(I_j)}} \quad \dots\dots (viii)$$

Varieties j and j' will be significantly different if the calculated t is larger than the tabulated t for the 5% of probabilities and $(r-1)\ (p-1)$ degrees of freedom.

The former test is not correct to make the comparison of all possible pairs of varieties. The adequate procedure is the one called "Sequential Test of the Amplitude" (3).

Coefficients a_k.—We have said that the index to measure variety j which has successive yields $k=1, 2, \dots q$ may be of form

$$I_j = \sum_{k=1}^{q} a_k R_{jk} \quad \dots\dots (ix)$$

in which R_{jk} is the mean yield of variety j in season k and a_k is the coefficient weighing said yield.

a_k is a coefficient that may be determined with various judgments. One, perhaps the more convenient, would be applying the economic concepts of the actual value of the profits obtained in each season. If we suppose that the the production cost of season k is equal for every treatment, which is mostly true for case of this set of varieties, and we call it C_k, the profit of treatment j during season k will be

$$G_{jk} = R_{jk} - C_k \quad \dots\dots (x)$$

and its actual value, referred to the time of the first crop, will be :

$$G'_{jk} = \frac{G_{jk}}{(1+i)^{k-1}} = \frac{R_{jk} - C_k}{(1+i)^{k-1}} \quad \dots\dots (xi)$$

in which i is a given rate of interest.

The actual profit of treatment j shall be called G_j and will be :

$$G_{jk} = \sum_{k=1}^{q} \frac{1}{(1+i)^{k-1}} (R_{jk} - C_k) \quad \dots\dots (xii)$$

In general, the fundamental purpose of an experiment is the ability to compare the treatments among them and establish a criterion to consider one of them as better, equal or worse than the other. The comparison of two treatments j and j' would be made with the difference G_j-G_j', but we can easily see that

$$G_j - G_j' = I_j - I_j' \quad \dots\dots (xiii)$$

Therefore, for the comparison of the treatments there is no need to consider the costs of production in each season if it is assumed that they are equal for every treatment though different for each season. We can also conclude that coefficients a_k may adopt the following form :

$$a_k = \frac{1}{(1+i)^{k-1}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (xiv)$$

and index I_j to measure treatment j is then :

$$I_j = \sum_{k=1}^{q} \frac{R_{jk}}{(1+i)^{k-1}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (xv)$$

The variance of I_j is, applying formula (5)

$$V(I_j) = \frac{1}{r} \left\{ \left[\frac{(1+i)^q - 1}{i(1+i)^q - 1} \right]^2 \times \sigma_2^2 + \frac{(1+i)^{2q} - 1}{(1+i)^{2q-2} \left[(1+i)^2 - 1 \right]} \times \sigma_1^2 \right\} \ldots\ldots (xvi)$$

or also :

$$V(I_j) = \frac{1}{r} \left(A_q \sigma_2^2 + B_q \sigma_1^2 \right) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (xvii)$$

Factors A_q and B_q can be calculated in advance and are constant for a same rate of interest i and for a number of seasons q in which an experiment is fulfilled. r is the number of replications of the treatments. These values for different i and q appear in Table II. Values for $i=0$ correspond to consider the successive crops of equal importance, that is, $a_k=1$.

TABLE II

VALUES OF A_q AND B_q

	$i=0.00$		$i=0.04$		$i=0.05$		$i=0.06$		$i=0.07$	
q	A_q	B_q	A_q	B_q	A_q	B_q	A_q	B_q	A_q	B_q
1	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2	4.00	2.00	3.85	1.92	3.80	1.91	3.76	1.88	3.76	1.88
3	9.00	3.00	8·35	2.77	8.18	2.74	8.07	2.68	7.90	2.64
4	16.00	4.00	14.30	3.59	13.91	3.44	13.40	3.36	13.18	3.30
5	25.00	5.00	21.44	4.32	20.60	4.13	19.98	4.02	19.27	3.86

	$i=0.08$		$i=0.09$		$i=0.10$		$i=0.11$		$i=0.12$	
q	A_q	B_q	A_q	B_q	A_q	B_q	A_q	B_q	A_q	B_q
1	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2	3.72	1.85	3.69	1.84	3.65	1.83	3.61	1.80	3.57	1.79
3	7.73	2.58	7.62	2.54	7.51	2.49	7.34	2.46	7.24	2.42
4	12.74	3.25	12.46	3.17	12.18	3.08	11.90	3.00	11.56	2.92
5	18.58	3.75	17.98	3.64	17.39	3.54	16.81	3.44	16.32	3.35

EFFECT OF THE CONTINUANCE OF THE EXPERIMENT DURING VARIOUS SEASONS IN THE NUMBER OF REPLICATIONS

The number of replications of the treatments in the experiment is intimately bound to the accuracy of the estimates of their effects and consequently in the efficiency of their comparisons. Cochran and Cox (2) establish the following relation between these two concepts :

$$r=2\left(\frac{\sigma}{\partial}\right)^2 \times \left(t_1+t_2\right) \ldots\ldots\ldots\ldots \textit{(xviii)}$$

r is the number of replications of the treatments; σ is the standard deviation of the experimental error ; ∂ is the magnitude of the difference between effects that the experiment is to detect; t_1 and t_2 are values of Student's t to know the magnitude of the significant difference and to determine the probability with which the experiment detects ∂ respectively, they depend on the number of degrees of freedom of the experimental error, and as this number depends on r, the solution of (*xviii*) is obtained by trial and error.

Formula (*xvii*) has been established for annual crop experiments but may be applied to perennial or semi-perennial crops. The formula would be :

$$r_q=2\times\left(\frac{\sigma_{(q)}}{\partial_{(q)}}\right)^2 (t_1+t_2) \ldots\ldots\ldots\ldots \textit{(xix)}$$

in which r_q is the number of necessary replications of an experiment held during q cycles in order to be able to detect a difference $\partial_{(q)}$ when the standard deviation is $\sigma_{(q)}$. This may be determined from the following expression:

$$\sigma^2_{(q)} = A_q\,\sigma_2^2 + B_q\,\sigma_1^2 \ldots\ldots\ldots\ldots \textit{(xx)}$$

$\partial_{(q)}$ may be expressed as a fraction of the mean value of the I_j (See formula (15).

$$\partial_{(q)}=m\bar{I}_{(q)} \qquad \ldots\ldots\ldots\ldots \textit{(xxi)}$$

in which

$$\bar{I}_{(q)}=\frac{1}{p}\sum_{j=1}^{p} I_j$$

Index $_{(q)}$ serves to indicate that it refers to q seasons.

Substituting (*xxi*) in (*xix*),

$$r_q=\left(\frac{\sigma_{(q)}}{m\bar{I}_{(q)}}\right)^2 (t_1+t_2) \ldots\ldots\ldots\ldots \textit{(xxii)}$$

If we consider that the values of t_1 and t_2 are not appreciably modified, we can write :

$$r_1=\left(\frac{\sigma_{(1)}}{m\bar{I}_{(1)}}\right)^2 (t_1+t_2) \ldots\ldots\ldots\ldots \textit{(xxiii)}$$

From expression (*xxii*) and (*xxiii*) we find

$$r_q=r_1\left(\frac{\sigma_{(q)}}{\sigma_{(1)}}\right)^2\left(\frac{I_{(1)}}{I_{(q)}}\right)^2 \ldots\ldots\ldots\ldots \textit{(xxiv)}$$

The former equality relates the number of replications of an experiment on a perennial crop continued through q years with the number of replications of an experiment on an annual crop, both experiments having the same accuracy. The values of $\sigma_{(q)}$ and $\sigma_{(1)}$ may be estimated with formula (*xx*) if knowledge is had of σ_1^2 and σ_2^2 through another similar experiment already performed. The values of $\bar{I}_{(q)}$ and $\bar{I}_{(1)}$ may be supposed according to the possible successive yields.

Observing equation (*xxiv*) we find that r_q will be less than r_1 when

$$\frac{\sigma_{(q)}}{\sigma_{(1)}} < \frac{\bar{I}_{(q)}}{\bar{I}_{(1)}} \quad \text{...}(xxv)$$

II—APPLICATION

EXPERIMENT

A comparative test of 12 sugarcane varieties was established in 1950 at the Experiment Station of Ingenio del Mante, Mexico, taking Co. 290 and POJ 2878, the commercial varieties in the zone, as checks.

The experimental design was "Randomized Blocks" with 4 replications; the plot was of 6 rows of 20m at a distance of 1.20m between rows; the two side rows were eliminated for the analysis of the experiment, leaving an effective plot of 96m².

The first harvest in cane plant was given in January 1952 and in February 1953 the first ratoon crop was obtained. Due to bad conditions of the field where the test was located, the experiment was suspended after the second cut.

DATA

The cane yields for each plot appear in Table III ; data are presented in a way to facilitate the necessary calculations for the analysis of variance.

TABLE III

EXPERIMENT WITH 12 VARIETIES. YIELDS IN CANE PLANT AND RATOON--KG. PER 96 m² OF PLOT

		REPLICATIONS							
		I		II		III		IV	
S. No.	Varieties	Plant	Ratoon	Plant	Ratoon	Plant	Ratoon	Plant	Ratoon
1	Co. 210	512	280	466	338	535	290	550	120
2	Co. 301	958	516	921	400	931	433	766	349
3	POJ 2878	584	215	475	205	374	362	321	160
4	Tuc. 1376	696	395	892	437	668	335	666	235
5	Co. 331	752	450	931	468	760	409	701	366
6	CP. 27/48	500	365	577	450	592	345	624	340
7	Co. 312	691	420	701	285	628	200	580	190
8	Co. 290	596	350	674	280	532	230	542	216
9	CP 29/137	627	332	562	318	457	195	504	230
10	Co. 421	996	558	796	345	834	300	753	307
11	B. 6385	622	325	521	310	560	245	452	235
12	Co. 281	747	206	692	260	666	200	531	225

RESULTS

Mean yields converted into Ton/Ha. in cane plant and first ratoon of the 12 varieties, appear in Table IV. Considering a rate of interest $i=0.12$, the valuation index for each variety will be :

$$I_j = R_1 + \frac{R_2}{1+0.12}$$

in which R_1 is the cane plant yield and R_2 that of the first ratoon. The values of I_j appear in Table IV.

TABLE IV

EXPERIMENT OF VARIETIES—MEAN YIELD AND INDEX OF VALUATION TON/HA.

S. No.	Variety	Cane Plant	Ratoon	I_j
1	Co. 210	53.72	26.77	77.62
2	Co. 301	93.12	44.22	132.60
3	POJ 2878	45.67	24.53	67.57
4	Tuc. 1376	76.10	36.51	108.70
5	Co. 331	81.17	44.09	121.23
6	CP. 27/48	59.71	39.06	94.58
7	Co. 312	67.70	28.51	93.15
8	Co. 290	61.04	28.02	86.06
9	CP. 29/137	55.99	27.99	80.98
10	Co. 421	87·99	39.32	123.09
11	B. 6385	56.12	29.03	82.04
12	Co. 281	68.64	23.20	89.35
	Total	807.67	391.25	1156.97

ANALYSIS

Our problem is to compare the I_j of the different varieties in order to determine if they are significantly different among them, in which case we need to know the variance of I_j, $V(I_j)$.

With this purpose we obtained the analysis of variance appearing in Table V.

TABLE V

EXPERIMENT OF VARIETIES—ANALYSIS OF VARIANCE CALCULATED WITH YIELDS, Kg/96m²

Source of variation	Degrees of freedom	Sum of squares	Mean square	Expected mean square
Replications	3	191965	63988.6	
Varieties	11	906920	82447.3	
Error (1)	33	151644	4595.3	$\sigma_1^2+2\,\sigma_2^2$
Sub-Total	47	1250529		
Seasons	1	2663667	2663667.5	
Seasons x Var.	11	205127	18648.0	2
Error (2)	36	123206	3422.4	σ_1^2
Total	95	4242531		

From the analysis of variance we estimate :

$$\hat{\sigma}_1^2 = 3422(\mathrm{Kg}/96\mathrm{m}^2) = 37.13(\mathrm{Ton./Ha.})^2$$

$$\hat{\sigma}_2^2 = \frac{4595-3422}{2} = 586(\mathrm{Kg}/95\mathrm{m}^2)^2 = 6.35\ (\mathrm{Ton/Ha.})^2$$

We have seen, formula (*xvii*), that :

$$V(I_j) = \frac{1}{r}\,(A_q\,\hat{\sigma}^2_2 + B_q\,\hat{\sigma}^2_1)$$

and in Table II we see that for $q=2$, $i=0.12$: $A_q=3.57$, $B_q=1.79$
Substituting, we have :

$$V(I_j) = 1/4\ (3.57 \mathrm{x} 6.35 + 1.79 \mathrm{x} 37.13) = 22.30\quad (\mathrm{Ton/Ha})^2$$

SIGNIFICANCE TESTS

The test of Student's 't' to know if there is any significant difference between two varieties taken at random, is:

$$t = \frac{I_j - I_j'}{\sqrt{2 \times 22.30}} = \frac{I_j - I_j'}{6.68} \text{ for 33 degrees of freedom.}$$

For example, in order to know if varieties Co. 421 and POJ 2878 may be considered different with regard to productive capacity, we would have (Table IV).

$$t = \frac{123.09-67.57}{6.68} = \frac{55.52}{6.68} = 8.30$$

In the t table, we find that for 33 degrees of freedom, Snedecor (6):

$$t_{.05} = 2.03, \quad t_{.01} = 2.72$$

As the calculated value 8.30 is larger than $t_{01} = 2.72$, we conclude that the difference between the two varieties is highly significant and therefore Co. 421 is quite superior to POJ 2878 in cane yields.

COMPARISON OF THE VARIETIES

We have said that Student's (t) test is only valid when the pair of treatments to be compared is selected at random. To detect significances within the different pairs that may be formed, the former test may lead to serious errors; it is then recommended to use the comparison method called "Sequential Test of the Amplitude" (3). For the application of this method the treatments are arranged as in Table VI, that is, in a descending order horizontally, and ascending vertically. The differences between the various pairs are calculated and to know if such differences are significant, we calculate the following value of :

$$W \hat{\sigma}$$

in which W is a tabulated value depending on the number of degrees of freedom with which $\hat{\sigma}$ has been estimated and on the number of treatments whose yields fell within the yields of the pair in comparison, $\hat{\sigma}$ is the standard deviation of the values of the treatments to be compared.

TABLE VI

EXPERIMENT OF VARIETIES-COMPARISON OF MEANS BY THE SEQUENTIAL TEST OF THE AMPLITUDE

Varieties		Co. 301	Col. 421	Co. 331	Tuc. 1376	CP27/48	Co. 312	Co. 281	Co. 290
	I_j	132.6	123.1	121.2	108.7	94.6	93.1	89.4	86.1
Co. 290	86.1	46.5* 21.6	37.0* 20.9	35.1* 20.0	22.6* 19.2	8.5 17.9			
Co. 281	89.4	43.2* 20.9	33.7* 20.0	31.8* 19.2	19.3* 17.9				
Co. 312	93.1	39.5* 20.0	30.0* 19.2	28.1* 17.9	13.6 16.3				
CP. 27/48	94.6	38.0* 19.2	28.5* 17.9	26.6* 16.3					
Tuc. 1376	108.7	23.9* 17.9	14.4 16.3						
Co. 321	121.2	11.4 16.3							
Co. 421	123.1	9.5							

In Table VI, only the varieties with an I_j value higher than that of Co. 290 have been compared, as this was one of the varieties used as check. We have two numbers for each pair of varieties: the upper one which is the difference between the I_j obtained and the lower one which is $W\hat{\sigma}$. If the first one is higher, both varieties are considered significantly different, which is pointed out with an asterisk.

We observe from Table VI that varieties Co. 301, Co. 421, Co. 331 and Tuc. 1376 are significantly superior to Co. 290. Co. 301 is superior to Tuc. 1376, etc.

EFFECTS OF RATOONING IN THE APPROXIMATION OF THE EXPERIMENT

If the experiment has been concluded with the crop corresponding to cane plant, we would have had, vide formula (19) and Table II:

$$\sigma^2_{(1)}=6.35+6.35+37.13=43.48$$

In Table IV the mean value of the yields in cane plant :

$$I_{(1)}=\frac{807.67}{12}=67.31$$

Having continued the experiment for one more cycle (first ratoon) we have :

$$\sigma^2_{(2)}=3.57x6.35+1.79\times 37.13=89.20$$

$$I_{(2)}=\frac{1156.97}{12}=96.41$$

and the relations :

$$\frac{\sigma_{(2)}}{\sigma_{(1)}}=\frac{89.20}{43.48}=1.43$$

$$\frac{I_{(2)}}{I_{(1)}}=\frac{96.41}{67.31}=1.43$$

are equal, so we can conclude that the continuation of the experiment in one more season did not result in a larger or smaller approximation in the determination of the treatments. If these are the conditions for other sugarcane experiments, a reduction of the repetitions when continuing an experiment in one or more cycles might not be possibly attained.

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Mr. N. S. Negi then presented the following paper.

Paper

AGRONOMIC RESPONSE OF SUGARCANE TO PLANT CLIPPING WHEN FERTILISED AT TWO LEVELS OF NITROGEN UNDER DIFFERENT SOILS MOISTURE CONDITIONS

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The purpose of this investigation was to study the response of 3 common varieties of sugarcane under different clipping levels of soil moisture and nitrogen fertilisation. An understanding of the responses of sugarcane crop to such varied agronomic treatments might lead to new ideas in farm practices and incidentally may also reveal factors responsible for lodging, not unoften a cause for low quality.

Washko (5) in 1947 found in Tennessee that grazing reduced grain yields of oats, wheat, barley and rye from 23.2 to 47.7%, depending upon the particular crop variety. Welton and Morris (6) in 1931 found in Ohio that clipping tended to reduce the number and height of culms in wheat and oat and militated against lodging. Cutler, Pavez, and Mulvey (1) in 1949 came to the conclusion that reduction in plant height combined with shortness of the lower internode was closely related to lodging resistance. Kirk, Davidson and Hamilton (2) reported that oats were superior to other cereal grains in yield of dry matter, percentage of protein and number of cuttings per season, where plants were cut at various stages to simulate grazing conditions. Muir and van Zwaluwenberg (3) in 1927 observed that pruning of cane leaves at three and a half months age cut down the height of plants and length and girth of internodes of stem. Went (7) found that defoliation of young cane plants resulted in decreased length and diameter of those internodes which had not yet completed their growth at the time of treatment. He further observed that with the formation of new leaves, the subsequent internodes gradually attained a normal size. Yamasaki and Arikado (8) found that removal of the leaves of the top section not only reduced the length and diameter of the defoliated joints, but also of all higher internodes formed subsequently. Stevenson and Southwell (4) found sugarcane to be a good roughage for winter feeding of cattle in Georgia.

MATERIALS AND METHODS

Tests were designed to study three varieties of sugarcane Co. 453, Co. 513 and B.O. 24 during the year 1952-53. These varieties have been under cultivation in the white sugar belt of Bihar as also in the other neighbouring States. The experiment was conducted at Pusa on well-drained calcareous soil.

Co. 453 is an erect, medium thick and high yielding cane with moderate tillering capacity. Co. 513 is an erect and thin cane with profuse tillering capacity. B.O. 24 is intermediate in tillering and thickness of the stem between Co. 453 and Co. 513. Besides, it is specially suited for low lands where water logging conditions exist.

A triple split plot design with three replicates was adopted to accommodate all the 24 combinations of variety, doses of nitrogen, soil moisture conditions and clippings. The single plot consisted of four 22-foot rows from which the central two rows were harvested leaving 3-foot on each side. The planting was done on 18th Feb. 1952. The cane varieties were planted in the main plots, each consisting of 8 parts for as many treatments. There were 2 levels of nitrogen, 60 lbs. and 120 lbs. N, with no irrigation and two irrigations, with two clippings and no clipping; and their different combinations.

The plants were cut back twice 2″ above the last visible dewlap on April 15 and July 22. The clipped material was weighed immediately and recorded as weight of fodder.

At the time of plant maturity, data were obtained on yield, sucrose content, plant height and tillering of the cane varieties. The data were subjected to statistical analyses to assess the significance of the various treatments.

EXPERIMENTAL RESULTS

The response of the three varieties with regard to yield, height of plants, tillers per clump, stalk diameter, sucrose percentage and yield of fodder under different treatments is presented in Table I. The data have been further summarized in Tables II and III. A summary of the significance of the main factors and their interactions are presented in Table IV.

Yield: A reference to Tables I and II will show that Co. 453 was significantly superior in yield to Co. 513 and B.O. 24. The difference in yield between the later two varieties was non-significant. Clipping significantly reduced yield, the reduction being more pronounced in Co. 453, less in B.O. 24 and least and non-significant in Co. 513. While the differences in yields of Co. 513 and B.O. 24 were negligible and non-significant in non-clipped plots, the differences under clipping treatment almost approached the least significant value (Table II).

A closer inspection of Table I will show that yield decreased due to clipping under all combinations of nitrogen and soil moisture levels though only interaction of nitrogen and soil moisture was significant. Compared to non-clipped plots under 60 lbs. nitrogen with no irrigation all other clipping treatments reduced yield of Co. 453 and B.O. 24.

Sucrose: Although variations in sucrose percentage were not significant yet the trend indicates that it was favourably altered by clipping in Co. 513 and B.O. 24. Co. 453 on the other hand showed lower sucrose percentage under clipped condition except under higher dose of nitrogen with no irrigation.

Tillering: Co. 513 produced significantly higher number of tillers than Co. 453

TABLE I

YIELD IN LBS./PLOT SUCROSE PERCENTAGE, TILLERS/CLUMP, PLANT HEIGHT, STALK DIAMETER AND YIELD OF FODDER UNDER DIFFERENT COMBINATIONS OF VARIETIES, CLIPPINGS, NITROGEN AND SOIL MOISTURE

	I_0				I_2				
	N_1		N_2		N_1		N_2		
	C_0	C_2	C_0	C_2	C_0	C_2	C_0	C_2	
Yield in lbs./plot									
Co. 513	67.3	60.7	82.7	86.0	86.0	75.3	78.0	80.7	77.0
Co. 453	115.3	84.7	151.3	97.3	127.3	90.7	117.3	87.3	109.0
B.O. 24	72.0	52.0	76.0	68.0	89.3	60.7	92.7	62.0	71.6
Mean	84.9	65.8	103.3	83.8	100.9	75.6	96.0	76.7	
Sucrose %									
Co. 513	17.54	16.71	16.49	16.61	17.13	17.56	16.78	17.36	16.94
Co. 453	17.42	17.11	16.44	17.23	17.68	16.93	17.54	16.97	17.17
B.O. 24	17.02	17.44	16.76	16.90	17.19	18.23	16.69	17.66	17.24
Mean	17.33	17.26	16.56	16.91	17.33	17.57	17.00	17.33	
Tiller/Clump									
Co. 513	5.73	4.46	5.33	4.5	5.56	4.6	5.0	5.1	5.04
Co. 453	4.43	3.06	3.5	3.73	4.0	3.66	3.6	3.46	3.69
B.O. 24	4.03	2.3	3.76	3.4	3.3	3.23	4.03	3.4	3.44
Mean	4.73	3.27	4.20	3.88	4.29	3.83	4.21	3.99	
Plant height in inches									
Co. 513	104.16	86.33	88.9	91.23	103.36	97.86	106.3	96.73	96.89
Co. 453	114.96	105.83	120.2	106.1	116.26	111.76	121.43	109.7	113.28
B.O. 24	124.73	113.03	119.16	110.46	110.46	110.8	119.2	118.8	115.83
Mean	114.62	101.73	109.42	102.6	110.03	106.8	115.64	108.41	
Stalk diameter inches									
Co. 513	0.72	0.69	0.74	0.72	0.75	0.70	0.70	0.69	0.72
Co. 453	0.94	0.93	0.93	0.90	0.96	0.92	0.96	0.90	0.93
B.O. 24	0.88	0.78	0.82	0.80	0.76	0.78	0.73	0.80	0.80
Mean	0.85	0.80	0.83	0.80	0.82	0.80	0.80	0.80	
Yield of fodder in lbs.									
Co. 513		17.53		20.11		21.3		18.46	19.35
Co. 453		20.66		19.31		21.25		25.20	21.60
B.O. 24		10.73		13.64		18.68		22.66	16.44
Mean		16.31		17.68		20.41		22.17	

I_0=No irrigation. N_1=60 lbs. Nitrogen. C_0=No Clipping.
I_2=Two irrigations. N_2=120 lbs. ,, C_2=Two Clippings.

TABLE II

EFFECTS OF CLIPPING ON YIELD, SUCROSE PERCENTAGE, TILLER/CLUMP, PLANT HEIGHT AND STALK DIAMETER

		Co. 513	Co. 453	B.O. 24	60 lb. N_2	120 lb. N_2	Irrigation		Mean	C.D. at 5%
							Nil	Two		
Yield in lbs.	C_0	78.40	127·60	80.24	92.80	99.60	95.00	98.40	96.70	Var.=18.84 N = 8.06 N × I =11·0 C = 8·50 C×V=15.48
	C_2	75.60	90.00	60.00	70.60	80.20	74.60	76.00	75.30	
	Mean	77.00	108.80	70.42	81.70	89.90	84.80	87.20		
Sucrose %	C_0	16.91	17.27	16.92	17.28	16.79	16.89	17.17	17.03	N = 0.33
	C_2	16.98	17.06	17.56	17.33	17.07	17.00	17.40	17·20	
	Mean	16.94	17.26	17·24	17.30	16.93	16.95	17.29		
Tiller/Clump	C_0	5·41	3.90	3.79	5.52	4.22	4.47	4.26	4.36	Var. = 0.77 C = 421
	C_2	4.67	3.48	3.08	3.56	3.93	3·58	3.91	3.74	
	Mean	5.04	3·69	3.43	4.04	4·08	4.02	4.08		
Plant height in inches	C_0	100·68	118.22	118.39	112.33	112.53	112.02	112.84	112.43	Var. = 13.41 C = 3.28
	C_2	93.04	108.35	113.28	104.27	105.51	102.17	107.61	104.89	
	Mean	96.86	113.28	115.83	108.30	109.02	107.17	107·09		
Stalk diameter in inches	C_0	0·73	0.95	0.80	0.84	0.82	0.84	0·81	0.82	Var. = .052
	C_2	0.70	0.91	0.79	0.80	0.80	0.81	0.80	0.80	
	Mean	0.71	0.93	0.795	0.82	0.81	0.825	0.805		

and B.O. 24, there being but little and non-significant difference between tillering capacities of the latter two. Clipping on the whole reduced number of tillers significantly. All the three varieties registered a lower tillering due to clipping though the differences were statistically non-significant. Adverse effect of clipping on tillering was also visible under almost all combinations of soil moisture levels, varieties and doses of nitrogen. The effect tended to be more severe under non-irrigated condition.

Plant height: Clipping reduced plant height on the whole significantly. Among the varieties the largest, though non-significant, reduction was noticeable in Co. 453 followed by Co. 513 and B.O. 24. There was not much difference in plant height due to different levels of nitrogen and soil moisture conditions in non-clipped plots but the differences were pronounced in clipped plots (Table II). None of the differences was, however, significant at 5% level. Adverse effect of clipping was evident in all individual treatments.

Stalk diameter: Stalk diameter was not appreciably influenced by clipping though a non-significant but consistent reduction was discernable under all treatments in all the varieties.

Yield of fodder: A summarised data regarding yield of fodder obtained as a result of clipping are presented in Table III. A perusal will indicate that Co. 453 yielded largest quantity of fodder followed by Co. 513 and B.O. 24, the differences between varieties, however, being statistically non-significant. Application of additional nitrogen did not have any significant effect on yield of fodder though the data showed an increase with 120 lbs. nitrogen in Co. 453 and B.O. 24. Irrigation on the other hand increased yield of fodder significantly in case of B.O. 24 followed by Co. 453. The substantial increase in yield of fodder in B.O. 24 due to irrigation brought the variety on par with other two in this respect. Considering the treatments individually it is evident that all the three varieties produced less fodder without irrigation under lower dose of nitrogen.

TABLE III

INFLUENCE OF SOIL MOISTURE CONDITION ON YIELD OF FODDER OBTAINED AS A RESULT OF CLIPPING

	No Irrigation	Two Irrigations	Mean	60 lbs. N_2	120 lbs. N_2	Mean	Mean in mds.
Co. 513	18.82	19.88	19.35	19.41	19.29	19.35	37.34
Co. 453	19.99	23.22	21.60	20.96	22.25	21.60	41.68
B.O. 24	12.12	20.68	16.40	14.72	18.16	16.44	31.73
Mean	17.00	21.26		18.36	19.90		
Mean in mds.	32.81	41.03		34.44	38.40		

C.D. at 5%

Irrigation = 2.25

Variety × Irrigation = 3.92.

TABLE IV

SUMMARY OF SIGNIFICANCE OF THE MAIN FACTORS AND THEIR INTERACTIONS

Crop response	Main factors and their interactions							Remarks
	Variety	Clipping	Nitrogen	Irrigation	Variety × Irrigation	Variety × Clipping	Nitrogen × Irrigation	
Yield	1**	1	5*	...*	...	1	5	Other inter-actions were not significant
Sucrose	...	...	5	...	.	...	...	
Tillering	5	1	...	...	...	...	...	
Height	5	1	...	...	...	...	...	
Stalk diameter	1	...	...	...	...	...	...	
Weight of fodder	...	...	...	1	5	...	...	

* Significant at 5 % level

** Significant at 1 % level

DISCUSSION

Adverse effects of clipping on various morphological characters and yield were evident under the experimental conditions. But in case of Co. 513 the adverse effect with regard to cane was statistically non significant. In fact this variety registered increased, though non-significant, yield due to clipping with 120 lbs. nitrogen. This as also the fact that clipped plots, except those under no irrigation and 60 lbs. nitrogen, had higher yield compared to non-clipped plots with no irrigation and 60 lbs. nitrogen point out to possible beneficial effect of clipping in Co. 513. Number of tillers in Co. 513 though reduced in clipped conditions was still higher than the other two varieties under similar condition and may acccount for the small and non-significant reduction in yield of this variety.

Plant height as also stalk diameter were reduced due to clipping. The varietal reaction was not so evident with regard to these characters.

Sucrose unlike morphological characters was favourably influenced by clipping, Co. 453, however, showing deviation from this trend. But none of the differences were statistically significant.

Response was similar with the higher level of fertilisation except in Co. 513 where more fodder was produced under lower level of soil moisture condition. Fodder yield also decreased both in irrigated and non-irrigated plots under lower levels of fertilisation except in irrigation treatment in Co. 513 and no irrigation treatment in Co. 453.

From the point of view of obtaining fodder, Co. 513 appears to be the best variety though it produced slightly less fodder than Co. 453. Though clipping effected an over all non-significant decrease in yield in Co. 513, the treatment actually tended to produce beneficial effects under 120 lbs. nitrogen as also under 60 lbs. nitrogen with 2 irrigations. Co. 453 on the other hand would be most severely effected if subjected to clipping under the variations mentioned. Unlike the other two varieties it may also suffer a set-back with regard to sucrose percentage B.O. 24 besides producing a smaller weight of fodder would also suffer significantly with regard to yield.

Clipping is expected to create lodging resistance in varieties, an important aspect of the problem which could not be studied because of unfavourable weather conditions for lodging.

Studies with more favourable moisture conditions and with profusely tillering varieties like Co. 513 may yield results of greater consequence.

SUMMARY

Field experiments were conducted on well drained calcareous soils at Pusa Farm, Bihar, to study the response of three varieties of sugarcane to clipping under different levels of soil moisture and nitrogen fertilization. The three varieties represented varying tillering capacities.

Clipping significantly reduced yield of sugarcane by 22.1%, the reduction being more pronounced in Co. 453 less in B.O. 24 and least and non-significant in Co. 513.

Sucrose percentage, on the other hand, was favourably altered due to clipping by 0.99%, though the difference was non-significant.

Tillering was also adversely affected by clipping to the extent of 14.4%. The effect tended to be more severe under non-irrigated conditions.

A significant reduction of 6.7% in plant height was also noticeable.

Stalk diameter although not appreciably influenced by clipping showed consistent reduction under all treatments.

The weight of fodder obtained as a result of clipping was highest in Co. 453 (41.68 mds./acre) followed by Co. 513 (37.34 mds./acre) and least in B.O. 24 (31.73 mds./acre). Two irrigations significantly increased yield of fodder by 25.5%. Increase due to additional 60 lbs. nitrogen was 11.5%.

Results indicate Co. 513 as the best variety considered from the point of view of both fodder and cane yield. Co. 453 on the other hand would be severely affected.

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SOIL SECTION

SOIL SECTION

Session—Tuesday, 28th January, 9-15 A.M.

Dr. B. K. Mukerji, *Chairman*

The Chairman delivered the following address.

Gentlemen,

It is indeed a matter of privilege and pleasure to me that I should be able to meet at this conference many of the notable personalities of the Sugar World, and especially some who are engaged in making detailed studies of the sugar cane soils. That a Section of Soil Science has now been created by the Society is a clear evidence of the realisation of the need and importance of acquiring a full and intimate knowledge of the soils in formulating any scheme of sugar cane improvement, with a view to ensuring higher tonnage, better juice quality and building up and conserving soil fertility. I am deeply conscious of the responsibilities imposed on me in guiding the deliberations of this Section, and it is my earnest desire that we should all discuss our main problems as fully as possible within the short time at our disposal and formulate definite lines of action for the over-all improvement of sugar cane cultivation in all the cane growing countries which are yet comparatively underdeveloped in that respect.

The sugar industry in the present day world is passing through a period of crisis. Much of this is primarily due to the defective planning of sugar cane cultivation, which does not permit of the maximum resources available in some of the countries being fully exploited to the benefit of the growers and the industry alike. I firmly hope that our deliberations would lead to pooling of knowledge which would equip us better in performing our common duty, namely, greater service to the sugar cane growers and the sugar industry in all the sugar producing countries of the world.

I propose to put before you certain aspects of soil classification and the nutrient status of the sugar cane soils; and I trust you would be good enough to bear with me if I base some of my observations purely on my personal experience, although they might appear to be somewhat unorthodox and deviating from the views commonly held.

The great disparity that exists to-day in the Sugar World in respect to the tonnage of cane and sugar recovery per acre is indeed amazing. There is hardly much co-ordination amongst the constituent countries in respect to planning of sugar cane cultivation, and facilities are also lacking for enabling those countries which occupy comparatively unfavourable position to secure first hand information and knowledge from the more advanced countries.

Much credit is undoubtedly due to Hawaii for holding the premier position, as she does, in respect to the tonnage and quality of sugar cane among the sugar producing countries of the world. This may largely be attributed to the excellent sugar cane research organisation functioning in that country. Australia, Cuba and Mauritius also occupy a high place. But India with a total area under sugar cane of about 4 million acres, which is almost equivalent to 35 percent of the World's cane area, is lagging far behind in respect to both the yield and quality of cane. India is the only country among the sugar cane growing countries of the world having such a large acreage under cane. The Indian sugar industry, including jaggery and open pan sugar, is the largest in the world. The total production in India amounts to about 5 million tons out of the world's total production of 24 million tons of cane sugar and 38 million tons of cane and beet sugar. But in spite of such remarkable achievements it is sad to record that the yield and quality of sugar cane in India happen to be the lowest in the world. The average yield of sugar cane in India is about 14.1 tons per acre and the recovery percent of sugar 9.98. The present unsatisfactory position could mainly be attributed to lack of knowledge in respect to the suitability of the varieties in the different sugar cane growing tracts in the Indian Union,defective planning and shortcomings in the matter of sugar cane development. All these factors come largely in the way of the sugar industry in this country being so well regulated and stabilised as in some of the other important sugar producing countries of the world.

In respect to the inherent genetic qualities of sugar cane now being propagated in India, it may be stated that yields of cane ranging between 60 to 80 tons per acre have actually been secured even under the comparatively unfavourable natural conditions prevailing in North India. This would certainly tend to prove that sugar cane varieties are responsive to cultural factors—perhaps to a greater extent than to climatic conditions which are commonly regarded to constitute almost the sole basis in formulating plans for sugar cane cultivation. The fact that such high yields can be obtained by individual farmers even under adverse climatic conditions strengthens the view that even if the climatic factors are responsible for low yields, their adverse influence could be counter-acted by adopting suitable cultural practices. This would, if I may be permitted to say so, indicate that there is an urgent need for modifying in some countries the present policy of sugar cane breeding.

It is now an accepted fact that the observed differences in varietal performance, including time of ripening, are mainly due to the differences in the soils, climate, and the manurial and other cultural treatments. The results obtained at various research stations clearly go to show that there exists an interaction between the types of the root system and the types of the soil. Resistance to drought, waterlogging and alkalinity is also mainly correlated with the root system of the sugar cane varieties. Varietal differences being subordinate to soil, climatic, manurial and other cultural treatments, the main objective of our breeding policy should be the production of a range of varieties best suited to the normal and sub-normal environmental conditions in the different soil-climatic regions of a country. For this purpose, wherever possible, centres for the breeding of cane must be located in the problem areas themselves. Should that not be practicable due to the inherent difficulties involved in the production of viable seeds, as in North India, intensive selection programmes may be undertaken in a large number of centres by raising seedlings from hybrid fluffs and planting seedling setts of the promising varieties issued from the main Breeding Institute. This alone will enable us to produce for every region varieties of sugar cane, possessing desirable agronomic features.

Varieties respond differently to manuring which has a profound influence on the quality and yield of sugar cane. And manuring is primarily correlated to the inherent nature of the soil. In breeding sugar cane varieties, therefore, attention must also be concentrated on evolving such varieties in particular which show the best response to every pound of fertiliser applied to the soil.

In order to improve the quality of cane and increase the yield per acre, the following are of general importance :—

(*i*) Introduction of improved varieties of cane of early, medium and late maturity, which should be of high sucrose content, and resistant to the attack of diseases and pests.

(*ii*) Judicious management of soils in order to maintain the yield and quality of the sugar cane crop and the fertility of the land at a high level.

While the importance of the sugar cane crop in countries like India which have a variegated pattern of soil, climate and cultural practices, is fully admitted, we find ourselves as yet hardly in a position to either correlate yield and quality of cane with those conditions, or give definite advice in regard to the economic use of fertilisers, with special reference to the nature of the soils, varieties grown and irrigation facilities available in the different regions. Since almost each of the improved varieties reacts differently to different soil conditions, much difficulty is always experienced owing to lack of information on the nature of the surface and sub-soils, in assessing beforehand with any degree of certainty the ultimate possibilities of success of such varieties in a particular tract.

As a result of the extensive soil studies made in recent years in Australia by Prescot, 28 great soil groups are now recognised in that country. Hardy and co-workers in Trinidad have also thrown much light on the soils in general of British West Indies. Sharrad in South Africa and Sampio in Portuguese East Indies have recorded interesting observations on the performance of cane varieties in the alluvial basin soils. A good deal of soil survey work has also now been undertaken in Mexico and four major soil associations, as noted under, have been recognised in the cane growing regions in that country.

(*i*) Latosals; (*ii*) Low calcimorphic soils; (*iii*) Black soils (Chernozems); and (*iv*) Chestnut soils.

These soils are generally described to be clayey or clay-loams and they are neutral or alkaline in reaction.

While a fair amount of information exists on sugar cane soils of volcanic origin and acid in reaction, very scanty information appears to be available, excepting in India, on sugar cane soils of colluvial-alluvial nature, or halomorphic soils containing varying quantities of calcium, both in the free state or in the clay complex.

The recognition of the importance of soil to the sugar cane has come about chiefly due to the realisation that further progress in securing notable increases in the yield of sugar cane by breeding and selection can only be possible through improvements in cultural practices. The methods of appropriate crop rotation, manuring and irrigation must be relied upon to a greater extent for securing increased yields; and soil conditions have to be studied in detail for planning measures of improvements on rational and scientific lines.

All of us who deal with tropical soils know that due to normal erosion processes several different but related soils are formed from the same parent material. On high lands we may have skeletal soils which may be highly sandy or containing too many gravels or stones or secondary ferruginous crusts. At the depressions the soils may be of very fine texture containing colluvial-alluvial products of degradation from high elevations. Thus the slope conditions would mainly determine the character and sequence of horizons.

In the study of soils for the improvement of the sugar cane crop, soils could profitably be characterised not only by their inherent attributes but also by those properties which have subsequently been acquired by them through human agencies. The parameters of the attributes on the basis of which soils of the temperate countries are classified are often found inadequate for fully characterising the sugar cane soils of the tropics and sub-tropics. I might make this point clear by a special reference to soil structure and the colour intensity of the soils.

Under temperate conditions due to slower oxidation of organic matter the soil structure is well defined and fully developed; but under tropical conditions mainly owing to an accelerated rate of oxidation of the organic matter, the soil structures are very weakly developed. Thus the division of soils into fine granular, granular or crumby structure may not be understood to mean the same thing in the two climatic belts. The colour intensity of the soils—depending as it does on their moisture content, would vary under different degrees of desiccation. This view of tropical soils is not obtained in the temperate countries where rainfall is more or less uniform in the different months, and the soils are not subject to that degree of drying as is usual in the dry summers of the tropics and sub-tropics. Stability of soil aggregates against the impact of rain is one of the important factors for agricultural characteristics of the soils; and in any system of classifying soils subject to heavy monsoonic rains this fact should also be taken into consideration. The colour of the cementing material contributes very largely to the actual colour phenomenon of the individual soil groups in the tropics. The collective behaviour of soils towards crops, manures and irrigation in alluvial basins indicates that the limits of particle size generally adopted for characterising soils as ‘Sandy-loam’, ‘Silty-loam’ or ‘Clayey’ in temperate countries are not applicable to the tropical conditions. All these features of soil morphology must be taken into consideration for the characterisation of the soils in the tropics, hot temperate and humid tropics.

The examples cited above are merely illustrative and by no means exhaustive. It may thus be seen that there is considerable scope for a measure of pioneering work in soil systematics in the sugar cane growing countries. One must be circumspect in applying *in toto* the experience gained in soil work in the temperate regions to the conditions, say, as obtained in the sugar cane soils in India.

I propose now to briefly review the more important features of the sugar cane soil survey work so far conducted in India. Soil survey of sugar cane lands has been in progress in this country for more than the last two decades, and the increasing demand for soil classification—both by the industry and the growers, is an indication of the value that is attached to the scientific knowledge of soils in sugar cane development. The results obtained here could be of some value in the appraisal of the soil conditions and the principles underlying soil management in many other sugar cane growing countries of the world.

Sugar cane is grown in India under widely varying soil and climatic conditions. In the Deccan tract an application of 375 lbs. of nitrogen is considered by no means excessive; while in the Ganga basin in the North an application of over 150 lbs. of nitrogen has been found to be generally ineffective. The normal growth period of sugar cane in the Deccan tract is about 18 months; whereas in the plains of the Ganga basin the cane crop takes 10 months to attain full maturity. In Madras State the quality of cane is poorer even than that in the Ganga alluvium in the North. In other tracts there is considerable variation both in respect to yield as well as quality of cane. Experimental work carried out within each State has revealed widely different response to manuring.

The effect of the nature of soils on the yield and quality of sugar cane has been brought out in some cases very clearly by the Indian workers. In Uttar Pradesh it has been seen that the lighter alluvial basin soils tend to increase cane tonnage but reduce cane quality. From Bihar it has been reported that as a result of water-logging an inordinate increase of invert sugar, total colloids, gums, pectins, non-protein nitrogen and ash occurs in the cane juice. Under water-logged conditions over 90 percent of the total nitrogen was found by the Bihar workers to be existing in a non-protein form, which accounted for the very poor quality of cane. From a large number of manurial trials carried out in Uttar Pradesh, it has been found that under normal irrigation, the yield increases vary according to the textural characteristics of the soil. Against an average yield of 230 lbs. of cane per lb. of nitrogen in sandy basin soils, the corresponding yield of cane in clay loam varies only between 74 and 94 lbs. In another series of experiments it has been found that increase in the soil salinity reduces yield and increases the non-sugar percent. in juice. Much valuable information on these lines is available for the sugar cane soils of the Deccan canal tracts in Bombay.

The lines on which the survey of the sugar cane soils are carried out in India may be regarded as unorthodox; since the differentiating characteristics adopted are those which within a geographical unit are found to be the most important factors in growth and development of sugar cane. For such a classification, the inherent features of the soil types have been relegated to a comparatively unimportant position. In Peninsular India, where soil formation has taken place on rocks of prearchean period, the drainage characteristics have been considered as most important for classifying and characterising sugar cane soils. In North India, on the other hand, the composition and character of the parent alluvium as well as soil topography have been assigned a position of top priority. At the lower category level the hydromorphic and orographical characteristics have been found important from the point of view of cane growth.

The black cotton soils of Bombay-Deccan, specially those under sugar cane cultivation, have been classified by Basu and collaborators into 12 soils classes belonging to the genetic group of Tropical Immature Chernozem. These on the basis of drainage characteristics have been divided into two families at high category level. The classification at the lower category level has been based on the considerations of chemical composition and physico-chemical properties. It will thus be observed that the system adopted by Basu is one of physical land classification suited for characterization of irrigability of lands. In Uttar Pradesh, in the North, the classification adopted is based on the age of the alluvial deposits. At the highest category levels the soils of this area have been divided into two families, viz., the fresh alluvial soils and old alluvial soils no longer subject to inundation. At the next level of classification the soils have been divided on the basis of drainage characteristics into two groups, viz., soils with impeded drainage and soils which are well drained. At the lower category levels the soils have been further divided into soil types and soil phases. The principles followed for surveying the sugar cane soils in the Punjab are basically similar to those for Uttar Pradesh. A reconnaissance survey of the sugar cane soils of Bihar was first carried out by Prasad and collaborators. In the north of the river Ganga, the entire area is marked by variations of rainfall and humidity. The soils forming a part of the old Ganga alluvium have been characterized as calcareous and those in the extreme north in close proximity to the foot-hills of the Himalayas as non-calcareous. In the south of the Ganga the soil types have been divided, according to their texture, into clay and sandy formation in the alluvial basin; but in areas where the soil formation is essentially sedentary in character, the classification is based mainly on the colour of the soil, e.g., reddish-brown, etc.

For the immediate purpose of demarcation of land types for determining the suitability of soils for sugar cane, a basic *land* classification rather than *soil* classification appears to be necessary. For the determination of the soil properties in a strictly pedological sense the relative significance of different characteristics—morphological, mechanical and physical is the same; but for the purpose of classification of land with a specific objective, the basic requirements of the objective constitute the important deciding factors as to the significance to be attached to the different soil characteristics. The unorthodox bias in soil classification adopted by the sugar cane soil workers in India is, therefore, fully justified for the purpose of achieving the immediate objective. Such an approach to soil studies has as much scientific value as classification of soils according to the recognised concepts of pedology.

While the need for nitrogenous manures and fertilisers is universally felt, the utility of adding potassium and phosphorus is by no means so obvious. By and large, however, the available experimental evidence proves that application of potassium does not in general lead to any notable increase in the yield of cane or sugar per acre. But the utility of phosphorus is now being realised as a result of the appreciation of the fact in recent years that fruitful results will emerge only when the phosphatic fertilisers are placed at a region of the soil easily accessible to the roots of the growing crop. Another factor to which intensification of research on the utility of phosphatic fertilisers could be attributed is the knowledge that has now accumulated on the function of phosphorus in enhancing the nitrogen content of the soil and the need for setting up therein a correct N:P balance. Some light has also been thrown on the mode of absorption of phosphorus by the root hairs of the cane crop.

Hawaiian soils show a high degree of variability. The younger soils are high in available phosphorus, but the more weathered soils with better drainage facilities have a comparatively poor phosphate status, due presumably to loss of silica and the concentration of hydrated oxides of iron and aluminium. There is clear indication from the results obtained in that country that the available phosphorus content is dependent to a large extent on the soil forming parent material and the stage to which they are weathered. The nature of the drainage conditions, however, functions as the decisive factor. Phosphate is generally added in Hawaii in moderate doses, not exceeding 50 lbs. per acre, whereas the normal crop extracts some 45 lbs. These soils are reported to have a tremendous capacity of fixing phosphorus.

In Jamaica little response to nitrogen is evinced by sugar cane on red lateritic soils; but most of the other soils respond to ammonium sulphate. Economic response with phosphorus is obtained only on red soils, poorer clay soils and some calcareous hill soils. Potassium deficiency is greatest in presence of excessive free limestone.

The vertical distribution of available phosphorus and potassium is recorded by Tsun-Tien Chao and Fon-Ven Lee for 56 samples from Western Taiwan. In the highly leached lateritic soils—the ferruginous nature of which tends to fix phosphorus, both available phosphorus and potassium are extremely low throughout the full depth of one metre. Occasionally higher values are obtained in the top 20-30 cm. when sub-soil application of fertilisers and liming are found to be beneficial. In the alluvial soils available phosphorus is relatively high. These soils are, however, characterised by extreme irregularity in the vertical distribution of phosphorus, a feature attributed to earlier fertiliser applications.

Schroo summarising the results of his investigations conducted at the Imperial College of Agriculture, Trinidad, has observed that the concentration of phosphate ions in the soil solution is the result of a multi-factorial equilibrium between the soil and the liquid phases of the soil, and that the phenomenon of phosphate fixation does not, in point of fact, imply the entire quantity of the available phosphate being rendered unavailable to the growing plant. That the plant roots may enter into active competition with phosphate binding forces of the soil has been substantiated by a carefully conducted experiment which has clearly brought out the fact that to obtain the best results with 'phosphatic fertilisers, it is essential that the contact area between the phosphated soil and the active root hair surface should be enlarged, so that a very large proportion of the active root surface could participate in the process of phosphate absorption. For practical purposes, therefore, it appears desirable that in order to obtain effective results the phosphatic fertilisers should be dispersed over as large an area as possible of the surface layer. Better results are likely to follow if small dosages of phosphate are diluted with a large volume of soil. In view of the extreme immobility of the phosphate ions in the soil, it may be uneconomical to apply large dosages of phosphatic fertiliser for raising the total phosphate status of the soil. The presumption of the author that the cane varieties differ in their ability to explore the phosphate sources of the soil because of genotypical and phenotypical differences of the root systems certainly calls for detailed investigation.

Villanueva and Gallardo while reporting the results of their studies of the Mexican sugar cane soils have recommended that phosphorus and potassium plus a small amount of nitrogen should be applied before planting at bottom of the row, and the remaining nitrogen when the plants have reached some 30 cm. in height. The fertilisers according to these authors are to be placed at one side of the rows. In some cases band placement at both sides of the row is also recommended.

Lad, Raghvan and Patel, working on the sugar cane soils of Bombay-Deccan in India corroborate the findings of the American and also some other Indian workers that soluble phosphatic fertilisers are rendered unavailable in calcareous soils. This is, as is well known, ascribed to certain chemical and physical reactions following the addition of phosphatic fertilisers to calcareous soils. The exact nature of the physical reactions is, however, not clearly understood as yet. In this connection it will be interesting to note the observations of Schroo in the paper presented by him at this Congress that better results obtained through liming in acid soils, may be attributed to improved functioning of the plant roots. But that liming has an effect of enhancing the efficiency of soluble phosphatic fertilisers has been very well brought out by Gokhle in his study of the laterite soil of Ratnagiri district in the State of Bombay in India. This soil does not show even a trace of phosphate on extraction with water alone or with carbonated water. It has also a very high P-fixing capacity. These factors account for the high response of the soil to phosphate manuring. Large quantities of soluble phosphate will, however, have to be added to the soil before there can be any release of phosphate for the use of plants. The beneficial effect brought about by the application of calcium carbonate has been attributed by the author to the greater availability of phosphate to the plant, as a result of carbonated water dissolving a part of the added phosphate fixed in the soil.

There is thus a great need for undertaking detailed investigation on these lines, for elucidating the various points which yet remain obscure in the phosphate fertilisation of acid sugar cane soils.

Application of phosphate in a band or row is claimed by Lad and co-workers in India to result in 30 to 40 percent of the applied P_2O_5 being available. The best results have been obtained by them through placement at 6 inch depth in the furrow for deep soils and half-way down the ridge in shallow soils. This conclusion could have been better appreciated if the results were correlated with the spread of the roots of the more important cane varieties in the different soils. In common with observations made by some of the leading workers in this subject, these authors have also concluded that the availability of phosphate is enhanced very markedly when applied through carriers like bulky organic manures. Their data further show the nature of the influence of phosphatic fertilisers in improving to a marked extent the nitrogen status of the soil. This result deserves wide publicity; since even though phosphatic fertilisers by themselves may not be of much value in leading to an increased yield of sugar cane, they do help in rendering a large proportion of inert nitrogen into an available form. The most curious thing, however, is that in spite of such large accumulations of available nitrogen being thus brought about in the soil, the addition of phosphate by itself does not seem to increase yields unless supplemented by nitrogenous fertilisers or manures. This obviously leads one to the cogent fact that in order to secure beneficial results of any lasting value, it is necessary to condition the soils, so to say, to a correct balance of Carbon : Nitrogen. The increase in available nitrogen as evinced by the addition of phosphatic fertilisers is somewhat similar to the increase observed through the fixation of nitrogen by *Azotobacter*, the population of which is enhanced very markedly through the addition of acid phosphates. In such studies, therefore, it appears very desirable that the soils be examined carefully in respect to the changes brought about in the nitrogen-fixing organisms by the addition of artificial fertilisers—nitrogenous, phosphatic and potassic.

While efforts have been made to study the physico-chemical and mechanical factors involved in the fixation and availability of phosphate in the soil, information on the transformations of phosphorus in the soil through micro-biological agencies is indeed scanty. It need hardly be emphasised that drawing up of a balance sheet of the phosphate added to the soil and that absorbed by the plant—so necessary for gauging the economic utility of phosphatic fertilisers for sugar cane, would be possible only when all the factors operating in the soil for synthesising and release of phosphorus—organic and mineral, are completely understood. One of the most important items of investigation would thus be an assay of the overall effect of the role of the sugar cane soil micro-organisms in bringing about the various transformations of phosphorus in the soil.

The new technique that is being developed for studying the nitrogen and phosphorus contents of soils by observing the reaction of isotope exchange, promises to be of considerable value in arriving at a satisfactory solution of the entire problem of the nutrient requirements of the sugar cane crop under varying environmental and cultural conditions. Interesting results have been obtained in Hawaii regarding the placement of aqua ammonia through the use of radio-active

N^{15}. It has now been established that a large interchange of nitrogen takes place in the soil among the soil micro-organisms, the reactive components of the soil and the growing plant. Goring in his experiments in Iowa, U.S.A., on the biological transformations of phosphorus in the soil has made an interesting use of P^{32} in determining the uptake of phosphorus by soil organisms and also the amounts of synthesised and mineralized organic phosphorus present in the soils. This author has now developed mathematical expressions for calculating quantatively the biological transformation of added phosphorus in the soil.

The lead given by Hawaii in the application of tracer elements in studying mineral transformations in the cane soil, should now be taken up at all such experiment stations where facilities could be provided for adopting the technique. The workers would first undoubtedly need some training in these methods, and I would appeal to the soil scientists engaged in similar work in Hawaii and other countries to offer suitable facilities for training at their Institutes. They would also be rendering a great service by publishing as frequently as possible the details of the methods followed by them and the results obtained.

I shall now briefly refer to the practice which is gaining popularity in certain countries of using fertiliser mixtures consisting of N, P and K. Although perhaps supported by theory, one has to be cautious in recommending any general adoption of such mixtures, especially from the point of view of economics. In South Africa, for instance, mixtures of fertilisers although more expensive than single fertiliser treatments, have become popular in sugar cane plantations. The results reported by Joyner and associates on the application of fertiliser mixtures to sugar cane soils in Louisiana are interesting and instructive. The field tests reported were almost completely negative. No additional yield of either cane or sugar could be attributed to complete fertilisation. A slight increase in yield was, however, obtained only as a result of increased nitrogen application. A scrutiny of the cane's normal nutrient requirements of potassium and phosphate in relation to soil analytical data indicates that in the Louisiana soils more than enough of these nutrients were already present in the soil before the fertilisers had been applied. This explains the lack of response to the cane at complete fertilisation.

The importance of soil analysis for interpreting the results of fertiliser experiments is obvious. The Louisiana workers have very rightly indicated the errors that a cane grower is apt to make—and the resulting false conclusions that may be drawn, when he attempts to check up the fertiliser requirements of the sugar cane crop on his own lands, without making an effort to correlate the manurial results obtained with the soil analytical data. The dogmatic tendency frequently displayed by the cane growers in the matter of fixing the nature and dosages of the fertiliser nutrients which could best be added to sugar cane fields in a particular region is most dangerous; since firm recommendations could only be based on a correct interpretation of the data obtained, and that could only be possible when a co-ordinated study is made of the soil composition, nutrients needed and the irrigational facilities available.

Finally, I should very much like to focus attention on the influence of sub-soil cultivation and manuring on the production of sugar cane. There are *a-priori* reasons to believe that due to the progressive increase in the use of heavy machineries on sugar cane plantations a certain amount of soil compaction is bound to follow. This will result in producing very significant changes in the infilteration capacity of the soil and consequent movement of the soluble nutrients in the soil profile. The need for sub-soil shattering might also arise when there is a hard pan layer at a certain depth, which would interfere with the natural course of the formation of the sugar cane roots. Sub-soil shattering is known to have produced excellent results in alkaline soils where the alkalinity is limited to a layer of hard pan at some depth.

Martinez and Lugo-Lopez have produced data showing the differences in sugar yields on a heavy clay pan soil in different treatments. The mean sugar yield of all plots receiving all the fertilisers on the top soil was 9,240 lbs. per acre ; the mean yield of all plots receiving half of the fertilisers on the surface and half on the sub-soil was 10,680 lbs. per acre. Filtration rates were increased on all plots by either sub-soiling alone or sub-soiling with mole-drainage. After sub-soiling, these heavy clays are reported to be capable of absorbing 4-5 times as much water as can clay pan layers which remain undisturbed by ordinary tillage.

In his interesting paper, embodying the results obtained from studies of soil compaction occurring at 8-12 inches depth in Terrebonne Parish, Louisiana, Davidson has shown that the average increase in compaction due to the use of heavy machineries in the sugar cane plantations are small, but significant for both light and heavy sub-soils.

Khazan Singh claims to have devised a soil compactometer with an automatic recording arrangement. It is portable and adaptable to spacing of 6 and 9 inches between the rows, and is reported to have given satisfactory results with soils varying from light to heavy resistances to penetration.

The entire problem of soil compaction must now be studied in all its details, and it is obvious that the role played by the soil structure is very significant for the purposes of such studies. As the compactness of soils is closely related to changes in soil structure, the state of aggregation of soil would undoubtedly afford very useful data.

Friends, I have already taken much of your time ; and I do not propose to multiply further instances emphasising the urgent need for a rational and detailed study of the sugar cane soils. A thorough and intimate knowledge of the soils is an essential pre-requisite to our achieving the desired objective of planning out sugar cane cultivation on a long term basis, for ensuring a high level of yield and quality without unduly taxing the inherent yield capacity of the soils. As I have already indicated, the sugar cane breeder has very grave responsibilities in this matter. It is obvious that we should breed canes specifically suited to the varying soil, climatic and cultural conditions prevailing in any region. The soil scientist and the agronomist must closely colloborate with each other in following up the work of the sugar cane breeder. The success achieved in being able to bring about a reduction in the cost of production of sugar cane would go a long way in stabilising the sugar industry in any country. This can largely be brought about through higher yield of sugar per acre. And higher yields would certainly lead to lower costs of production of sugar cane—a factor which in itself is quintessence to cheaper production of sugar.

I would suggest for your consideration the formation of an International Body of Soil Workers for co-ordinating the data available and also standardising the methods of sugar cane soil survey and analysis. Such an International Organisation would undoubtedly be best able to bring together the sugar cane soil workers all over the world and thus help, through pooling of knowledge, in providing effective solutions to many of the essential problems of sugar cane cultivation in the different parts of the world. I would accordingly seek your co-operation in giving a practical shape to this suggestion of setting up an International Committee of Sugarcane Soil Workers. Sugar cane soil studies all over the world should in future be conducted on a co-ordinated basis. An International Committee, the need for which is so strongly indicated, will serve as a clearing house for all available information on sugar cane soils of the world, so that we might be able to join hands in serving the best interests of the sugar cane crop in all its aspects.

Mr. Alfonso G. Gallardo presented the following paper.

Paper

GENERAL SCOPE ON THE MEXICAN SUGARCANE SOILS

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INTRODUCTION

Mexico is located between the 14° 30′ and 32° 30′ of north latitude and between the 86° 30′ and 118° 30′ west longitude from Greenwich, and has a total area of 1,964,000 square kilometers (758,300 square miles).

From the orographic, structural and physiographic points of view, Mexico forms a continental part of North America up to the Volcanic Range of Mountains (Volcanic Axis). To the South and SE. of this range, Mexico is more intimately related to Central America and the West Indies, forming part of the structural zone which Hill (1) called Orogenic West Indian System.

The Republic of Mexico is formed by 32 federal entities and may be considered, geographically, divided into 15 physiographic provinces. Sugarcane is cultivated in 28 of the 32 federal entities but cane for the elaboration of sugar is produced only in 16 of them. No cane is produced for the elaboration of sugar in the physiographic provinces of the Sierra Madre occidental, Sierra Madre del Sur, Sierra Madre de Chiapas, Mesa del Norte and Peninsula de Baja California.

The cane fields do not form a continuous area but are localised as scattered portions at altitudes ranging from sea level to 1,300 and 1,500 m., in the interior valleys of the country.

Climate in the cane regions is very varied, but the general features are: a tendency to small annual temperature's variation and great daily variation; scarce atmospheric moisture the most of the year in almost every cane region; Summer rainy season and any dry Winter season; moderate winds in the interior continental regions and violent winds from time to time because of the northerns in the Gulf of Mexico and the hurricanes in the Caribbean, which sometimes reach to the coasts of the Pacific Ocean.

With regard to rainfalls, half of the total area under cane cultivation is located at places where the annual precipitation is lower than 125 cm. (50″) and needs irrigation for cane cultivation. The other half has more than 140 cm. (50″) of annual rainfall and the cane fields are not irrigated generally; but the strong variation of effective annual rainfall and the dry periods, frequently of long duration, cause variations up to 50 percent in the cane yields from one year to another, which makes supplementary irrigation desirable and even necessary, in order to secure some uniformity in production.

According to studies made, the formation process of the Mexican cane soils, corresponds to calcification and latosolization which allows them to be included in the group of the Pedocals and Pedalfers (2). A soils association has been established for all these areas according to their dominant pedogenic process of formation, as follows :

1. Latosols with different intemperization degrees corresponding to supply zones of sugar mills located in the Gulf's watershed in the State of Veracruz.

2. Low Calcimorphic Soils in Tamaulipas Rendzines and Glei and Terra-Rosa in the south east of the country.

3. Black soils (Chernozems), pedocals and clayey in regions of relative altitude over sea level; e.g., the cane areas of Morelos, Puebla. Jalisco, Michoacan, etc.

4. Chestnuts, dominant in the western watershed, in the Pacific coastal and nearby regions.

In order to give an idea of the Mexican sugar cane soils and the activities developed in the study of their physico-chemical properties, a description of the categories of the zonal soils and their other fundamental characteristics in the different cane regions is given.

MEXICAN CANE REGIONS

The characteristics of the Mexican sugarcane soils vary greatly from one region to another and even within the same region. They are generally clays or clayey-loams; plastic, with great water retentive capacity and adsorption of cations, neutral and alkaline reactions even though in some latosol areas the pH is of medium acidity. They are well provided with calcium and magnesium, showing a high grade of base saturation—making liming unnecessary with certain exceptions. Generally the potassium level is high ; however, in Glei soils of the Tabasco region, the content is medium and rather low in some Prairie and Latosol areas; there is a great variation in the phosphorous level. All soils in Mexico are low in nitrogen. The content of organic matter up to 3 percent in some soils is not enough to favour the physical conditions due to the high clay content which makes it necessary to supply organic matter by means of rotations including legumes as green manure crops or grasses as cover crops and turning under of green plants for the benefit of the following crops.

But the majority of our cane soils may be considered as fertile. But lack of water, defective levelling, excess of soluble salts in the soil, unfavourable structure of the profile, soil erosion and bad internal drainage, depress their productivity. These cane soils, even with certain similar feature, differ in many aspects from the soils of the other cane producing countries of the world. Many of the Mexican sugarcane soils are of volcanic origin and intrazonal with the alluvial and colluvial ones predominating often with partial intemperized profiles.

The cane soils have been grouped into 16 cane regions limited by important natural formations and separated from one another by more or less large distances. These regions are sub-divided into zones, including those mills using the same or nearby shipping points.

A brief description on the geographic situation and natural conditions of the Mexican cane regions is as follows (3).

Region I—Sinaloa: Western Coast, between the 23° and 26° of N latitude and the 106° and 109° of W longitude, altitudes from 7 to 36 m.

Climate : Dry, with little or no seasonal excess of water and annual deficiency of 140 to 240 cm.; warm with uniform temperature regime.

The sugar mills in this region are :

Zone 1 (Los Mochis, Sin.)

2. Los Mochis

Zone 2 (Culiacan, Sin.)

3. La Primavera
5. Costa Rica (Rosales)
6. Eldorado

Zone 3 (Mazatlan, Sin.)

7. El Roble.

One hundred percent of the fields in this region are irrigated.

Slates and metamorphic rocks, limestones, lava and clays from the Precambrian to the Quaternary are observed. North of the Tropic of Cancer soils correspond to the Chestnut zonal province, with natural desert vegetation and thorny *chaparral* ; alluvial soils with clayey texture, alkaline, with pH over 8.0. Poor in organic matter, medium or high in P; low or medium in K. High in Ca and Mg with Na salts and free lime.

South of the Tropic of Cancer the soils belong to the Chernozem Mexican type, with grassy plain and tropical wood vegetation. Soils are of variable appearance, including some alluvial of loamy-clayey texture; neutral or slightly alkaline, low in organic matter; high in P and K. Very High in Ca and Mg.

Region II — Nayarit : Volcanic Axis, Sierra de Alica (Alica Range of Mountains) towards the 21° 30′ of N latitude and the 105° of W longitude, altitudes from 689 to 920 m.

Climate : Moderately humid, with rainfall deficiency of about 40 cm. in the winter and exceeding 20 to 25 cm. in the autumn; semi-warm with uniform temperature regime.

Zone 4 (*Tepic, Nay.*)

8. Puga
9. El Molino

50 percent of the fields are irrigated and the rest are under seasonal planting without irrigation.

The basic or parent material is formed by lava and basalt and andesite form the Tertiary and the Quaternary and lying undisturbed since they were deposited; recent alluvial soils, identified as yellow soils and red latosolic, with natural grassy-plain and tropical woods vegetation. These soils are very rich in clay with a good surface but a defective sub-soil drainage. The pH is 6.3, but due to a high base saturation, no liming is required. The organic matter content is fairly high, and the phosphate and potash contents are just medium.

Region III — Jalisco : South-West portion of the Central Plateau limited to the West by the Sierra Madre Occidental and to the South by the Volcanic Axis ; between the 19° 30′ of W longitude ; altitudes vary from 1,200 to 1,300 m.

Climate : Semi-dry with a deficient rainfall of about 50 to 70 cm. in the winter and about 8 cm. more in the autumn; semi-warm with uniform temperature regime.

Zone 5 (*Ameca, Jal.*)

10. San Francisco.
11. El Cabezon
13. Tala

Zone 6 (*Acatlan. Jal.*)

14. Estipac.
15. Bella Vista

Zone 7 (*Ciudad Guzman, Jal.*)

19. Tamazula.

About 73 percent of the area is irrigated and the rest is under seasonal planting without irrigation.

From the geological point of view stratified rocks and those partially transformed from the Paleozoic or the first part of the Mesozoic are identified. Sedimentary rocks from the Jurassic and Cretacic currents of lava and intrusions from the Tertiary, mostly basalts, andesites and riolites with quaternary calcsinters and clays are also encountered.

The soils are interzonal in character, belonging to the Chernozems (Mexican type) group with semi-steppary prairie vegetation and low mesquite grass land. The textures are clayey or sandy loam and loam. The soils are neutral or slightly alkaline in reaction, low in organic matter, medium in phosphate and rich in potash. They are also rich in Ca, Mg and exchangeable Na, even though without free salts.

Region IV — Colima : Counteforts of the Western end the Volcanic Axis, between the 19° and 19° 20′ N latitude and 103° 30′ and 104° West longitude; altitudes vary from 600 to 1300 m.

Climate : Semi-dry and dry with rainfall deficiency during most of the year - the total being approximately 90 cm. and with a small excess of 5 cm. in the autumn ; warm or temperate-warm with uniform temperature regime.

Zone 8 (Colima, Col.)

20. Queseria.
21. San Marcos.

Zone 10 (Tecalitlan, Jal.)

23. Santiago.
24. Purisima.
25. Guadalupe.

About 80 percent of the fields are irrigated and about 12 percent under cane of seasonal planting without irrigation.

The parent material is formed by lava and basaltic rocks from the Tertiary and the Quaternary. These are Prairie soils with Grassy-plain and tropical wood vegetation, of volcanic origin, with clay-loam texture, hilly topography and stony. Neutral reaction without excess of lime; and exchangeable Na in some places; low in organic matter, phosphate and potash.

Region V—Michoacan : At the Balsas Valley, on the Northern slope of the basin, between 18° 30′ and 19° 30′ N latitude and 100° and 102° 30′ W longitude. Altitudes vary from 300 to 1300 m.

Climate : Slightly humid and semi-humid, with deficient rainfall between 40 and 70 cm. in winter and about 10 to 15 cm. more in the summer ; semi-warm with uniform temperature regime.

Zone 11 (Los Reyes Mich.)

26. Santa Clara.
27. San Sebastian.

Zone 12 (Apaszinga n, Mich.)

29. Los Bancos.

Zone 13 (Uruapan, Mich.)

30. Iberica.
31. Taretan.
31.a. Tomendan.

Zone 14 (Tacambaro, Mich.)

32. Puruaran.
33. Pedefnales.

The fields are 100 percent irrigated.

The parent material is formed by basaltic andesite lavas from the Tertiary and Quaternary. The soils belong to the Shernozem (Mexican type) zonal group, residual, not very deep, undulated topography for hills with semi-steppary Prairie natural vegetation. Also includes Prairie soils with grassy-plain vegetation. The clayey fraction is abundant and are of neutral reaction, high in organic matter and potash, but medium to high in phosphate.

Region VI. Balsas : Balsas basin, between 17° 30′ and 19° N latitude and 98° and 100° W longitude ; altitudes vary from 600 to 1300 m.

Climate : Slightly humid and semi-dry, with a deficient rainfall of 60 to 120 cm. in the winter and 10 to 20 cm. more in the summer; warm to temperate-warm with uniform temperature regime.

Zone 16 (Cocula, Gro.)

35. San Martin.

Zone 17 (Cuernavaca, Mor.)

36. Cocoyotla.
37. Miacatlan.
38. Emiliano Zapata.
38.a Actopan.

Zone 18 (Cuautla, Mor.)

39. Oacalco.
40. Casasano.
41. Santa Ines.

Zone 19 (Matamoros, Pue.)

42. Atencingo.
43. Ixcateppan.

The entire area is irrigated.

The parent material is formed by a thick section of plaited clays and other sediments from the Jurassic and the Cretacic, and by lavas and intrusions of andesite, basalt and riolite from the Tertiary. The majority of the soils belong to the Chernozem group, occupying valleys of a mountainous region, with semi-steppary Prairie vegetation; some are Prairie soils with grassy-plain vegetation. These soils are generally of clayey texture but possess a good structure in the surface horizons and also an efficient internal drainage. The reaction is neutral or alkaline. Fairly provided with organic matter content is satisfactory but low to medium in phosphate and medium to high in potash and magnesia and some of the soils contain free lime and Na salts.

Region VII. Tehuacan : Skirts of the Western watershed of the Oaxaca Sierra, towards 18° 30′ N latitude and 97° 30′ W longitude; altitudes vary from 900 to 1100 m.

Climate : Dry with deficient rainfall all the year round, with a total of about 80 cm; semi-warm with uniform temperature regime.

Zone 20 (*Tehuacan, Pue.*)
44. Calipan.
45. Tilapa.

The entire cane area is irrigated.

The soil is found on gneiss, mica-schists and phyllites from the Precambrian era, a thick section of plaited clays and other sediments of the Cretacic and the Jurassic and lavas from the Tertiary.

Desertic, with dominant cactus, nopal and agave vegetation, slimy-clay texture dominant in these alluvial soils of small solum, resting on limy basement. Alkaline in reaction, pH 8.0, medium in organic matter, medium to high in P and K, high in Ca and Mg with some free lime. A certain amount of Na salts enter with the irrigation water.

Region VIII. Isthmus. Pacific coast, at the Tehuantepec Isthmus, between 16° and 17° latitude and 94° and 95° W longitude. Altitudes vary from 3 to 13 m.

Climate: Semi-dry, with rain deficiency of 100 cm. in the winter and the spring and excesses of 20 cm. in the autumn; warm, with uniform temperature regime.

Region VIII—A
Zone 21 (*Ixtepec, Oax.*)
Two sugar mills paralyzed.
The entire area is irrigated.
Region VIII—B
Zone 22 (*Cuatotolapan, Ver.*)
48. Cuatotolapan.
Zone 23 (*Popaloapan, Ver.*)
49. Paraiso Novillero.
50. San Gabriel.
51. San Cristobal.

The fields are under seasonal planting without irrigation, but in years of critical drought the cane suffers much because of lack of water.

The main geological formations belong to the Pleistocene and the Recent Eras. Prairie and latosol soils occur with natural grassy-plain and tropical forest vegetation. The soils are alluvial and clayey-loams in texture. They are slightly alkaline in reaction (pH. 7.6) and low in organic matter, P_2O_5 and K_2O, but high in Ca and Mg. Drainage conditions are good.

Region IX—Soconusco : Pacific coast, SE and at the limit with Guatemala, between the 14° 30′ and 15° N latitude and 92° 30′ W longitude. Average altitude 100 m.

Climate : Humid with a deficient rainfall of about 80 cm. in the winter and an excess of about 70 cm. in the summer; warm with uniform temperature regime.

Zone 24 (*Tapachula, chis.*)

At present only 2 "agurardiente" factories.

The cane fields are irrigated in the dry season.

Dominant rocks of the Pleistocene and Recent Eras with great abundance of effusive rocks and some intrusive from the Proterozoic.

Latosol zonal soils with tropical wood vegetation, alluvial with good drainage, pH 7.2, with high organic matter content and high P, K, Ca and Mg.

Region X—Yucatan : Yucatan Peninsula, between 19° 30′ and 20° 30′ N latitude and 89° and 91° W longitude. Altitudes range between 20 and 80 m.

Climate : Humid or very humid, with a slightly deficient rainfall of about 40 cm. in spring and a large excess in the summer and autumn of 80 cm; warm, with uniform temperature regime.

Zone 25 (*Tzucacab, Yuc.*)

55. Catimis.
56. Kakalna.

Zone 26 (*Haltunchen, Camp.*)

57. La Joya.

Forty one percent of the fields are irrigated and the rest of the area is under seasonal planting without irrigation.

Limy sediments from the Pleistocene and the Pliocene and limy rocks from the Pliocene at the Sierrita de Ticul. The soil correspond to the Province of Terra-Rosa with dominant thorny chaparral vegetation in the cane region due to the great permeability of the soil; neutral or alkaline in reaction. High in organic matter and K, medium in P; very high in Ca and Mg, with excess of free lime and some Na salts. Largely deficient in manganese and iron.

Region XI—Tobasco : SE coastal plain between the 17° 30′ and 18° 30′ N latitude and the 92° and 94° W longitude. Altitudes vary from 20 to 80 m.

Climate : Humid to very humid, with a deficient rainfall of about 40 cm. in the spring and a large excess in summer and autumn of about 80 cm.; warm with unifrorm temperature regime.

Zone 27 (*Jalapa, Tab.*)

58. Santa Ana, (Chis.)
59. Dos Patrias.
60. El Progreso.
61. La Union.
62. Santa Rosa.

Zone 28 (Cardenas, Tab.)

63. San Antonio.
65. Nueva Zelandia.
66. Santa Rita.
67. Santa Rosalfa.
68. San Candido.

Zone 29 (Lerdo de Tejada, Ver.)

70. San Francisco Naranjal.
71. San Pedro.

The entire cane area are under seasonal planting without irrigation.

The parent rocks belong to the Pleistocene and Recent Eras, as well as the Eocene and Miocene. The soils are latosolic with tropical wood and grassy-plain vegetation, alluvial clay-loam in texture with a neutral reaction, but there are acid soils at Tres Valles—pH 5.4—and alkaline at Parafso Novillero—pH 7.8. The soils are low in organic matter, P and K and high in Ca and Mg.

Region XII—Veracruz Central : Volcanic axis, eastern counterforts, between the 18° 30′ and 20° 30′ N latitude and the 96° 30′ and 98° W longitude. Altitudes range between 100 to 1,200 m.

Climate : Very humid and super-humid, with almost no deficiency of rainfall in spring and an excess of 70 cm. during the summer and autumn. Warm to temperate-warm, with uniform temperature regime.

Zone 30 (Motzorongo, Ver.)

72. La Margarita (Oax.)
73. Motzorongo.
74. La Providencia.
75. San Jose de Abajo.
75a. Constancia.

Zone 31 (Fortin, Ver.)

76. Jalapilla.
77. El Carmen.
78. Zapoapita.

Zone 32 (Corodoba, Ver.)

79. San Jose de Tapia.
80. San Miguelito.
81. San Francisco Toxpan.
81a. San Nicolas.

Zone 33 (Potrero, Ver.)

82. El Potrero.
83. Central Progreso.

Zone 34 (Coatepec, Ver.)

86. Mahuixtlan.
87. Tuzamapan.

Zone 35 (Naolinco, Ver.)

88. La Concepcion.

Four percent of the fields are irrigated and the rest are under seasonal planting without irrigation.

The parent material is formed of lava and basalt and andesite matters from the Tertiary and the Quaternary. Soils corresponding to latosolic and Chernozem groups with Sub-alpine woods and grassy-plain vegetation. Soils are generally thin and clayey in texture, acid, pH 6.0 and low in organic matter, P and K. Liming is necessary in some areas.

Region XIII—Costa Veracruz : Gulf's coast at the foot of the Volcanic axis between the 19° 15′ and the 20° 30′ N latitude and 96° 30′ and 97° 30′ W longitude. Altitudes vary from 10 to 150 m.

Climate. Semi-dry to humid with rain deficiency up to 80 cm. in winter and excesses of 10 to 20 cm. in summer and autumn; warm with uniform temperature regime.

Zone 36 (Villa Cardel, Ver.)

89. El Modelo.
90. La Gloria.

Zone 37 (Martinez de la Torre, Ver.)

91. Independencia.

All the fields are under seasonal planting without irrigation.

The dominant rocks belong to the Pleistocene and Recent Eras. Latosolic soils, with grassy-plain and tropical woods vegetation occur ; clayey alluvial in texture with deficient drainage. pH about neutral.

Region XIV. Huasteca : Gulf's coastal plain and counterforts of the Sierra Madre Oriental, between the 21° 31′ and 23° of N latitude and the 98° 30′ of W longitude ; altitude varies from 80 to 350 m.

Climate : Semi-dry to moderately humid, with a deficient rainfall up to 80 cm. in spring and excesses of 6 to 40 cm. in summer and autumn ; warm with uniform temperature regime.

Zone 38 (Valles, S. L. P.)

92. El Higo.
93. Tampaon.
94. Aguabuena.

Zone 39 (Mante, Tam.)

95. El Mante.
96. Xicotencatl.

Seventyseven percent of the fields are irrigated and the rest are under seasonal planting without irrigation.

Abundant rocks from the Cretacic era, metamorphic and sedimentary from the Jurassic, Tertiary and Quaternary.

Rendzines with thorny chaparral and tropical wood vegetation ; colluvial and alluvial soils, clayey, frequently of thin solum with clayey-loam basement ("choy"), badly drained, with soluble salts, and great excess of free lime which indicates a deficient production capacity. The plants show evident signs of nutritional deficiency notwithstanding that analyses show medium levels of organic matter, P and K. The high content of lime retains the iron and manganese and is considered as the main cause in the manifestation of chlorosis; the phosphorus is also immobilized.

STUDIES ON SOIL PROPERTIES AND OTHER FACTORS AFFECTING GROWTH OF CANE

1. *Soil Surveys and Cation and Anion Exchange Properties.* The soil surveys made correspond to El Mante, Tam., Xicotencatl, Tam., El Higo, Ver. and Calipan, Pue. sugar mills. Soil classification has been made according to the factors of alkalinity, drainage, topography and total soluble salts. Other preliminary soil surveys have been made in the cane areas of Rascon, S.L.P., Tampaon, S. L. P. and C. Valles, S.L.P. subsidiaries for the supply of the Mante and Xicotencatl sugar mills. These surveys have been made with the collaboration of the factories.

The exchange properties of cations and anions, the base saturation percentage and type of dominant mineral colloids that characterize the soils, have been determined in representative samples from the supply zones of sugar mills located between the 18° and 21° N latitude. The information obtained appears in Table I. "Exchange Properties of Cations and Anions in the Mexican Sugarcane Soils" (Ref. Lab. Procedure : Rapid Determination of Cation and Anion Exchange Properties and pH of Soils. A Mehlich Journal of the AOAC, May 1953—(4).

From the nutritional point of view, it is concluded that when exchangeable potassium is 1.0 m.e. per 100 gm. of soil, the cane requirements are satisfied ; but when this is lower than 0.5 m.e. symptoms of deficiency are liable to appear, especially on clays of the Illite type or in soils of sandy loam texture. Phosphorus determined as anion and frequently expressed in ppm is considered adequate when its level corresponds to 40 ppm.

An absorption capacity of 2 to 5 m.e. of Ca in the cane areas, corresponds to a nutritional level that varies from medium to high ; the same levels of Mg refer to 0.4 and 1.0 m.e. per 100 gm. of soil. Liming is unnecessary in soils saturated with 75 percent of basic cations, but is recommended in some latosolic soils with a large amount of exchangeable hydrogen.

The laboratory investigation indicates that the dominant types of clay in the Mexican sugarcane soils are the Illite, Montmorillonite and Kaolinite. Hematite and Gibsite also are identified in the latosolic zonal areas.

2. *Soils analyses and fertiliser recommendations.* In order to ascertain fertilizer requirements and the best methods of soil management, we have established a service of soil analysis, comprising 12 routine determinations and the study of salts when the soil pH is above 8.3. - The following procedures are

TABLE I

EXCHANGE PROPERTIES OF CATIONS AND ANIONS IN THE MEXICAN SUGARCANE SOILS

Soil No.	Place sampled	Zonal group	Cation exch. cap. m.e.	Exchangeable cations H m.e.	Ca m.e.	Mg m.e.	K m.e.	Na m.e.	Base sat. percentage	Anions Exch. capac. m.e.	C/A	pH	Type of colloidal mineral	Exch. PO 4 m.e. (o)
1.	Nueva Zelandia	Glei	34.0	0.4	28.3	3.44	0.62	0.33	100	19.5	1.7	3.2	I	2.0
2.	Nueva Zelandia		28.8	0.4	24.6	3.40	0.30	0.13	99	22.5	1.3	3.5	IK	0.9
3.	Santa Rita	Glei	39.4	6.4	25.3	7.94	0.35	0.12	84	18.0	2.2	3.1	I	2.0
4.	Santa Rita		38.6	6.8	21.7	7.90	0.34	0.16	82	26.1	1.5	3.1	I	1.2
5.	Eldorado	Glei	31.2	0.0	27.9	2.44	0.38	0.43	100	17.7	1.8	3.2	I	1.5
6.	Eldorado		27.4	0.0	25.6	3.42	0.20	0.48	100	15.0	1.8	3.1	I	1.1
7.	La Union	Glei	18.8	0.0	17.2	1.20	0.43	0.20	100	11.4	1.6	3.1	I	0.6
8.	La Union		50.4	0.0	45.1	6.56	0.67	0.11	100	22.8	2.2	3.0	I	3.3
9.	La Union		39.8	0.0	34.9	4.96	0.36	0.00	100	19.2	2.1	3.1	I	1.7
10.	Progreso	Glei	36.0	0.0	33.0	3.84	0.41	0.15	100	16.2	2.2	3.1	I	2.4
11.	Catmis	Terra-Rosa	79.6	0.0	76.7	6.56	2.30	0.50	100	30.9	2.6	3.0	M	9.1
12.	Catmis		83.0	1.0	73.7	8.00	1.04	0.83	98	32.4	2.6	3.0	M	7.3
13.	Kakalna	Terra-Rosa	33.4	0.8	23.2	3.84	2.23	0.10	98	23.4	1.4	3.5	IK	1.3
14.	Kakalna		77.2	1.6	67.6	8.80	2.40	0.35	98	39.3	2.0	3.0	I	6.2
15.	La Joya	Terra-Rosa	79.2	0.0	73.2	5.60	6.62	0.62	100	14.4	5.5	2.9	OM	5.1
16.	La Joya		47.6	0.0	54.9	4.32	2.97	0.16	100	5.7	8.4	2.9	M	8.5
17.	El Potrero	Latosoles	31.3	14.0	14.3	3.20	0.42	0.30	55	28.2	1.1	4.2	KHe	1.5
18.	El Potrero		19.4	11.2	6.9	1.80	0.15	0.28	42	26.1	0.7	4.5	KHeGi	0.2
19.	El Potrero		26.0	10.8	12.7	1.54	0.58	0.09	58	20.4	1.3	3.6	K	1.6
20.	El Potrero		24.1	18.3	3.2	1.78	0.25	0.15	22	32.4	0.7	4.5	KHeGi	1.0
21.	El Potrero		17.1	13.2	1.5	1.78	0.04	0.00	23	29.7	0.6	4.6	KHeGi	0.5
22.	El Potrero		34.0	16.0	12.4	3.20	0.37	0.00	53	25.5	1.3	3.7	K	1.7
23.	San Carlos	Chernozem	33.8	0.0	25.0	7.52	1.15	0.47	100	23.4	1.4	3.6	K	4.7
24.	Casasano	Chernozem	21.8	1.8	7.7	9.43	1.07	0.02	92	16.5	1.3	3.3	K	0.7
25.	Coahuixtla		26.8	5.8	9.6	8.90	0.35	0.33	78	25.8	1.0	4.0	KHe	2.7
26.	Potrerillos		32.0	7.2	10·4	12.53	0·64	0.26	78	33.6	1.0	3.8	K	0.6
27.	Potrerillos		28.8	7.2	10.4	8.44	1.34	0.24	75	29.4	1.0	4.0	KHe	0.9
28.	Pedernales	Chernozem	36.2	10.4	15.3	8·11	3.09	0.10	71	35.7	1.0	4.0	KHe	4.7

TABLE I—(*Contd.*)

Soil No.	Place sampled	Zonal group	Cation exch. capac. m.e.	Exchangeable cations H m.e.	Ca m.e.	Mg m.e.	K m.e.	Na m.e.	Base sat. percentage	Anions Exch. capac. m.e.	C/A	pH	Type of colloidal mineral	Exch. PO 4 m.e. (o)
29.	Pedernales		30.0	10.4	10.5	9.24	1.20	0.16	65	34.2	0.9	4.1	KHe	1.8
30.	Santa Cruz	Prairie	21.6	0.0	18.5	2.88	0.49	0.00	100	15.6	1.4	3.2	K	0.9
31.	Santa Clara	Chernozem	23.4	6.8	8.3	6.08	1.01	0.00	71	25.2	0.9	3.9	KHe	2.6
32.	Santa Clara		26.4	8.4	9.9	6.56	0.94	0.16	68	35.7	0.7	3.9	KHe	0.7
33.	Temazula	Mount Complex	20.2	1.2	12.9	4.08	0.88	0.33	95	13.8	1.5	3.1	I	1.0
34.	Temazula	Chernozem	31.6	1.0	13.5	4.32	0.41	0.26	95	15.0	1.5	3.0	I	0.5
35.	Bellavista	Chernozem	18.8	2.4	8.5	3.84	1.51	2.45	87	14.1	1.3	3.3	IK	1.3
36.	Bellavista		22.8	3.2	12.4	5.36	1.73	1.36	86	13.8	1.7	3.1	I	2.3
37.	Guadalupe	Mount Complex	17.2	3.4	7.5	4.88	0.97	0.03	80	9.3	1.8	3.1	I	1.2
38A.	Guadalupe		20.0	2.4	10.1	7.52	0.49	0.06	88	6.6	3.1	2.9	M	0.4
38B.	Puga		25.4	7.2	10.6	6.00	1.27	0.12	72	22.6	1.1	3.6	K	3.5
39.	Puga		17.5	8.4	5.7	3.68	0.55	0.10	52	23.1	0.8	4.0	KHeGi	0.9
40.	El Filo	Chernozem	28.1	5.2	16.7	4.64	2.26	0.00	81	10.2	2.8	3.1	M	5.9
41.	El Filo		25.1	2.0	18.3	5.10	1.15	0.07	92	8.4	3.0	3.1	M	3.0
42.	S. Francisco	M. Comp.	19.6	1.6	11.0	5.28	2.00	0.70	92	3.0	6.5	3.5	M	9.6
43.	S. Francisco		21.8	1.8	13.8	4.40	1.74	0.68	92	5.1	4.3	3.1	M	6.0
44.	Estipac	Chernozem	47.5	0.8	34.9	8.80	1.56	0.48	98	15.6	3.0	3.0	M	5.5
45.	Estipac		49.0	0.4	33.8	13.2	81.23	0.37	99	10.2	4.8	2.9	M	4.9
46.	Tala	Chrenozem	12.3	4.0	6.2	1.10	1.12	0.00	67	7.5	1.6	3.7	IK	3.1
47.	Tala		7.8	5.2	2.0	0.44	1.01	0.00	36	6.9	1.1	3.6	K	0.6

(o) These numbers should be cautiously interpreted while calibrated with field experiments.

O = Organic ; M = Montmorilonite ; I = Illite ; K = Kaolinite ; He = Hematite ; Gi = Gibsite.

followed for these rapid tests on soils : Bouyoucos, for the texture determination; Walkley and Black, modified UNPASA, for organic matter; Kjeldahl, modified N.C. Agr. Exp. Sta. for total nitrogen; and Morgan's for nutrients. (Ref. The Universal Soil Testing System, M.F. Morgan, Conn. State Agr. Exp. Sta. 333 pp. (111-132), illus., 1935). (5)

The samples of soils for analysis are sent to the laboratory by the interested farmers following the instructions attached or are directly collected by the staff of the Soils laboratory. More than 4,000 analyses of the soils of the 33 sugar mills have been made up to now, giving specific recommendations on fertilizer requirements and soil management.

Table II shows the recommendations on fertilizer referred to the N-P-K elements expressed in terms of fertilizer units (one unit equal to 10 Kgm. of N, P_2O_5 or K_2O). In some cases more than two formulae appear as different series and types of soils are identified in each supply zone whose morphology and physico-chemical properties differ.

Information on soil management and fertilization, edaphological characteristics of the soil, nutritional level indicated by the analysis and probable economic response of fertilizer formulae, are taken into account for the recommendations.

TABLE II

SUGARMILLS AND FERTILIZER RECOMMENDATIONS

Sugarmills and Zonal Group of Soils	Formula	Sugarmills and Zonal Group of Soils	Formula
Puga, Nay.	8 6 8	Cocoyotla, Mor.	10 8 6
(Mountain Complex)	8 6 6	(Chernozem)	12 8 4
	8 6 0		12 8 8
	6 6 6		8 8 6
			6 8 6
			Investig
El Molino Nay.	8 6 4	E. Zapata, Mor.	10 10 5
(Mountain Complex)	8 4 6	(Chernozem)	12 8 0
	8 6 0		
	6 6 6		
S. Fco. Ameca, Jal.	10 8 6	Oacalco, Mor.	12 10 6
(Mountain Complex)	8 6 0	(Chernozem)	10 10 5
	8 4 0		10 8 6
	6 6 4		8 10 4
Tala, Jal.	10 6 0	Casasano, Mor.	12 6 4
(Chernozem)	8 6 0	(Chernozem)	10 8 6
	6 6 0		8 6 0
			8 6 4
Tamazula, Jal.	10 6 4	Santa Ines, Mor.	10 8 4
(Mountain Complex)	10 6 0	(Chernozem)	8 6 6
	8 6 4		8 6 4
	8 6 0		8 6 0
			6 4 6

TABLE II—(*Contd.*)

Sugarmills and Zonal Group of Soils	Formula	Sugarmills and Zonal Group of Soils	Formula
Santa Clara, Mich. (Chernozem)	10 6 6 8 6 0 8 4 4	Atencingo, Pue. (Chernozem)	Investig. 12 8 4 10 8 4 10 8 0 8 8 4 6 8 4
San Sebastian, Mich. (Chernozem)	10 4 4 8 4 6	Calipan, Pue. (Interzonal desertic)	12 6 4 8 8 4 8 6 4 8 8 0 6 8 0
Tilapa, Pue. (Desert)	8 8 4	San Miguelito, Ver. (Latosol)	8 8 0 (Black soils) 10 8 6 (Red soils)
Cuatotolapan, Ver. (Latosol and Prairie)	10 8 8 10 6 4 8 6 4	El Potrero, Ver. (Latosol)	10 8 0 (Seasonal Planting red soils)
San Gabriel, Ver. (Latosol)	Investig.	Mahuixtlan, Ver. (Mount. Complex)	8 8 6 6 6 0 4 6 0
La Joya, Camp. (Terra-Rosa)	Phosphorus Magnesium & Minor Elem.	Tuzamapan, Ver. (Mount. Complex)	8 6 0
San Fco. Naranjal, Ver. (Glei)	6 4 4 6 6 0 4 6 6 6 0 0	El Modelo, Ver. (Latosol)	8 6 4 8 6 6 8 6 0 6 4 0
San Pedro, Ver. (Glei)	8 4 4 8 6 4 8 4 0 6 4 0	La Gloria, Ver. (Latosol)	8 6 4 6 6 4 6 6 0
La Providencia, Ver. (Red Soils)	10 6 8	Independencia, Ver. (Prairie)	6 4 0 4 6 4 4 6 0
San Jose de Abajo, Ver. (Latosol)	8 6 6 8 6 4 6 6 4	El Higo, Ver. (Rendzines)	Agrological survey.
San Jose de Tapia, Ver. (Latosol)	Investig.	El Mante, Tam.	Agrological survey drainage 6-8 Phosphorus Units.
Xicotencat, Tam. (Rendzines)	Agrological survey drainage 6-8 Phosphorus Units.		

We generally recommend that all the phosphorus and potassium, plus a small amount of nitrogen should be applied before planting at the bottom of the row, and the remaining nitrogen when the plants have reached some 30 cm. in height, placing it in rows whose depth does not harm the redicular system, covering it after depositing the fertilizer located at one side of the row plants.

3. *Field experimentation and its correlation with laboratory investigation.* Field experiments have been considered basic to calibrate the laboratory determinations and adjust the recommendations on fertilizers. The designs for the fertilizer experiments are factorial and are established at representative zones.

Fertilizers have been applied in bands at both sides of the row of plants or at one side in complete treatments at a certain age of the culture or by dividing the application of these in two or more operations. The experimental data are analysed statistically.

The results obtained from different fertilizer experiments in different soils are as follows.

(a) Experiment Station of El Mante, Tam. Type of Soil : Juarez Clay. Var. POJ 2878.—Factorial experiment 33 (4 replications) with 9 confounded interactions. Surface of effective parcel 72m^2 with 3 levels for the nitrogen, 0, 6 and 12; three for the phosphorus 0, 5 and 10 and three for potassium, O, 6 and 12. Conclusion: No significant difference among the different treatments and the check.

(b) Supply zone : Ingenio del Mante, Tam. Type of soil : Clay (Mante) (Black soils), Var. Co. 290. Factorial experiment in randomized blocks with 9 formulae and check, 4 replications, effective surface of parcel 72m^2. (Treatments : Check, 9-0-0, 0-6-0, 9-6-0, 0-0-6, 9-0-6, 0-6-6, 9-6-6, 6-0-0, 12-0-0). All referred to fertilizer units per hectare. Conclusions : No significant difference among treatments and check.

(c) Supply zone : Ingenio del Mante, Tam. Type of soil: Canton Clay (Black soils). Var. POJ 2878. Same type of experiment as (b), same treatments and replications. Conclusions : No significant difference among treatments and check.

(d) Supply zone : Ingenio del Mante, Tam. Type of soil : Humiferous Sauzal (March soils). Factorial experiment in randomized blocks. Var. POJ 2878. Parcels same size as the above. Treatments in terms of N, P, K units per Ha. with four replications: 0-0-0, 6-0-0, 0-9-0, 6-9-0, 0-0-6, 6-0-6, 0-9-6, 6-8-6, 0-6-0, 0-12-0. Conclusions: No significant difference among treatments and check.

(e) Supply zone: Igenio del Mante, Tam. Type of soil : Alluvian loams : Var. POJ 2878. Purpose of experiment : To observe the behaviour in factory yield. The experimental design was factorial in randomized blocks, total parcel comprised 5 rows and the useful parcel only 3. Length of rows : 15 m. separated 1.60 m. Experiment with 9 formulae and check ; 4 replications. Treatments : 0-0-0, 6-0-0, 9-0-0, 12-0-0, 0-9-0, 0-0-09, 0-9-9, 9-0-9, 9-9-0, 9-9-9. Conclusions : No significant difference between treatments and check.

As observed from the former studies, there are no significant differences among the effect of treatments, both in field and factory yields in these Rendzina zonal soils. Soils analyses indicate marked deficiency in phosphorus and other nutrients. This circumstance has given way to further investigations on the physical conditions of the soils, specially permeability, drainage, etc., as well as availability of other nutrients.

(f) Supply zone : Ingenio El Potrero, Ver.—Clayey texture soil. Latosol. Var. Co. 290 without irrigation. Experiment design made in quasilatin square, occupying a surface of 110.O m. × 88.2 m. The total parcel was of 6 rows of 10 cm. long, from which 4 constituted the effective parcel. Distance between rows was 1.40 m. Treatments comprised 27 formulae with 4 repetitions. Levels for N were : 0, 50 and 100 K/Ha; 0, 40 and 80 K. of P_2O_5/Ha for P; and 0, 40 and 80 K/Ha. of K O for potassium. The N was added as commercial manure, "Ne-green" (44% assimilable N). For other experiments $(NH_4)_2SO_4$ (20% N) was preferred because of being acidic residue; P as superphosphate (18.5% P_2O_5) and K as potassium muriate (50%K_2O). The quasi-latin square design proved advantageous in increasing the efficiency of the experiment, as both the rows and the columns eliminated a great part of the soil's heterogeneity. The analysis of variance showed that the effects of N only were significant and that there is an interaction of N with P. The additions of K did not cause any effect. Graph 1 shows clearly that the effects of N depend on the quantity of P.

CONCLUSIONS

Formula of fertilizers 10-8-0 proved to be the most suitable for this type of soils.

The laboratory determinations agree in this case with the field experiments.

4. *Influence of salinity in cane soils, drainage conditions and quality of irrigation waters.* The salinity in soils has shown its effects on productivity of the cane areas of El Mante and Xicotencatl, Tam., as well as in the fields of the supply zones of the Atencingo and Calipan, Pue., Emiliano Zapata, Mor., Costa Rica and Los Mochis, Sin. factories. In order to determine the class of salinity to which the affected areas belong, and the proper recovery treatments, a study of its properties is made to establish its classification. The classification of salty soils is as recommended by the U.S. Dept. of Agriculture (Table III).

TABLE III

CLASSIFICATION OF SALTY SOILS (U.S. REGIONAL SALINITY LABORATORY, RIVERSIDE., CAL.)

Type of soil	Electric conductivity of Saturation extract (in mmhos/cm. at 25°)	% Exchangeable Sodium	pH
Saline	4 or more	lesss than 15	Generally lower than 8.5.
Saline-alkaline	4 or more	15 or more	Seldom more than 8.5.
Alkaline	less than 4	15 or more	Generally more than 8.5.
Degraded	less than 4	15 or more	Generally between 6.5 and 8.0; sometimes lower than 6.0.

$$\% \text{ of exchangeable Na} = \frac{\text{Exch. Na (in m.e.100 gm. of soil)} \times 100}{\text{Exch. Cap. of Cations (m.e. 10 gm. of soil)}}$$

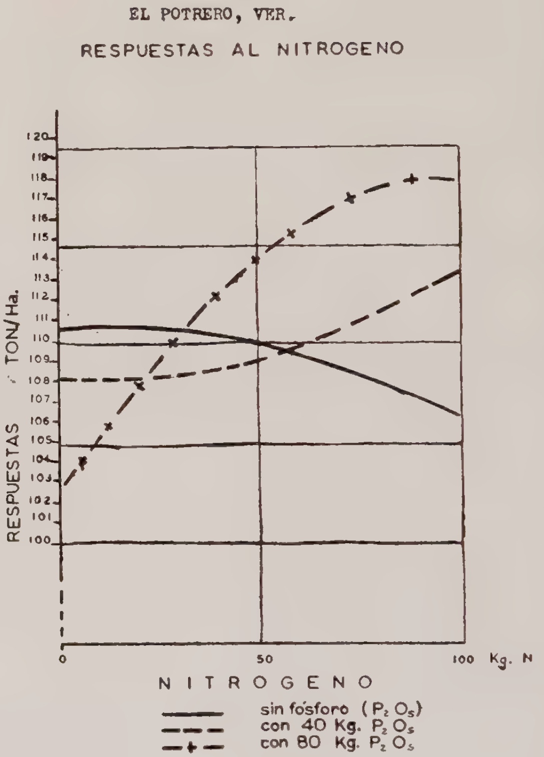
The laboratory determinations make it possible to conclude that the cane areas of El Mante and Xicotencatl, Tam., Atencingo, and Calipan, Pue., Zacatepec and Cacalco, Mor. correspond to the saline-alkaline types, even when in some localised areas the sodium retained by the colloidal complex is considerable.

If the superficial and internal drainage conditions allow it, leachings have been recommended for soils containing an excess of neutral soluble salts (sodium, calcium and magnesium chlorides and sulphates). Chemical amendments as gypsum or sulphur have been employed on alkali soils, in order to further displace the sodium and both treatments have been recommended for saline-alkaline soils—leaching and chemical amendments.

Drainage Conditions. The lack of adequate drainage facilities in soils containing salts constitutes the fundamental problem of the Mexican sugarcane fields. Permeability, as a direct function of the drainage conditions of the soils, has been studied following the method known as "Hydraulic conductivity" recommended by Christiansen (1947), Fireman (1944) and Richards (1952). (Ref. Diagnosis and Improvement of Saline and Alkali Soils. Agr. Handbook No. 60. U.S. Dept. of Agric. 1954). Darcy's law, which determines the coefficient of permeability in cm/h. is applied in this study (6).

After passing a volume of water equivalent to one irrigation through the column of soil, it is considered for the interpretation of the data obtained, that when the coefficient of permeability is lower than 0.25 cm/h., the drainage is critical; from 0.25 to 0.75 cm/h the drainage varies from unsatisfactory to good; from 1.75 to 7.5 cm/h drainage is considered good and more than 7.5 cm/h, drainage is excessive.

Quality of Irrigation Waters.—Irrigation waters as a factor of salinity in the Mexican sugarcane soils of arid and semi-arid climates, have been considered important due to the possible increase in concentration of the soil solution that might exceed the culture's permissible limits. The standards that have served to judge the type of available water in the irrigated areas, slightly modified, have been those recommended by Magistad and Christiansen, 1944 (7), as indicated in Table IV.



Gráfica 1.- Muestra las respuestas al nitrógeno solo y combinado con P_2O_5. Puede observarse la fuerte interacción entre los dos elementos.

Campos Experimentales UNPASA

TABLE IV

CLASSIFICATION OF IRRIGATION WATERS U.S. SALINITY LABORATORY, RIVERSIDE, CAL.

Type of water	Electric conductivity mmhos/cm. at 25°C.	Total content of salts in ppm.	% of Sodium	Boron ppm.
Class 1	1 or less	less than 700	60	less than 0.5
Class 2	1 to 3	700-2000	60-75	0.5-2.0
Class 3	3 or more	more than 2000	more than 75	more than 2.0

1.—Excellent to good, suitable for most plants under most conditions.
2.—Good to injurious, probably harmful to the more sensitive crops.

3.—Injurious to unsatisfactory, probably harmful to most crops and unsatisfactory for all but the most tolerant. Any class 3 water should be considered unsuitable, under most conditions. Should the salts present be largely sulphates the values for salt content for each class can be raised 50 percent. As soil, crop, climate, drainage and soil management all influence the suitability of water for irrigation, no simple classification scheme will hold for all cases.

The analysis of waters made up to now, correspond mainly to class 2 where sulphates are abundant.

Foliar Analysis as Indexes for Correction of Nutritional Deficiencies.—The analysis of plants, used as an index for the correction of nutritional deficiences of the cane, have been made in our investigations so as to be able to correlate at the first instance, the application of fertilizers with the effective absorption of the nutrients by the plants.

These analyses were started with Dr. Roger H. Bray's N-P-K kit, for colorimetric analysis, adopting later the procedures followed in Hawaii according to the recommendations of Dr. Harry F. Clements.

We have tentatively accepted as indexes for the normal growth of cane, on dry basis, those followed in Hawaii which are 2.0% for N (foliar analysis), 0.08% for P and 2.25% for K (sheath analysis).

The general conclusion is that adequate quantities of nitrogen should be applied at least in two phases of the culture's growth, medium to high doses of phosphorus and only complementary amounts of potassium.

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DISCUSSION

Sardar Harbans Singh wanted to know how the manurial schedules have been recommended when the field experiments did not give any response to fertilizers. He also enquired whether foliar analysis gave any correlation with the adsorption of nutrients. Further he desired to know why soils deficient in nitrogen did not respond to addition of nitrogen. In reply, the author stated that due to the high level of lime in the soil and its compact formation there was no response to nitrogen applications in the Intra Zonal Rendzina soils of El Mante, while the other soils of Mexico with 600 lbs. of sulphate of ammonia per acre gave high commercial yields (60 tons). The experiments on foliar diagnosis had been taken up only in one factory area and further work was in progress.

Mr. Girdhari Lal desired to know how the relationship between exchangeable bases and the low pH Values (Table I) could be explained. The author replied that low pH expressed in the paper was really exchangeable pH, the normal pH range in Mexican soils being 7—8.5.

Mr. M. A. Wali presented the following two papers. These were discussed together.

Paper

SOILS OF THE NIZAM SUGAR FACTORY ESTATE PART I

A. S. Srinivasa Murthy and M. A. Wali

The Nizam Sugar Factory Ltd., Shakarnagar, India.

LOCATION

The sugarcane estate, about 16,000 acres in extent, is situated in the Bodhan Taluqa of Nizamabad District, Hyderabad State. It is composed of isolated patches scattered within a radius of twenty miles from the factory situated at 77° 44′ long. and 18° 39′ lat. There is a minor hill range on the east and south-east of this area. It is drained by the Manjra, a tributary of Godavary, and the Godavary which flows along the west and north boundary of this area.

CLIMATE

The climate is characterised by a wide range of temperatures. The average temperature varies from 45° F. in winter to 112° F. in summer. The average rainfall is 40 inches and is mostly received during June to September, July and August being heaviest rainfall months. A short winter, December to January is followed by a long hot and dry summer.

GEOLOGICAL FORMATION

The rock formations consist mostly of grey Peninsular Gneisses that are conspicuously banded with bold crystals of hornblende and mica, and quartz and orthoclase felspar. Also found occasionally in the south-west is a pinkish gneiss, rather granitoid, consisting of quartz, microcline, orthoclase, acid plagioclase, some hornblende, mica and epidote. The grey gneiss lends itself to easy weathering, the most important mineral removed being felspar. The weathered rock is very porous and facilitates further weathering. On account of numerous crevices in the rocks, boulders are formed. These roll down the slope and encourage valley formation.

TOPOGRAPHY

The topography consists of a series of ridges and valleys interspersed with secondary ridges and valleys resulting in irregular drainage lines spread in all directions. The land is almost invariably undulating. The general elevation is between 1100′ and 1300′ above mean sea level.

SOIL SURVEY

When, in 1938, the factory decided to have its own plantations, the choice of land was strictly limited. The first two crops yielded 9 tons and 13 tons per acre over 1400 and 2300 acres respectively. For proper husbanding of the available soil resources to push up yields, a detailed study of the soils was necessary. Soils survey was started in 1942 and, but for a break of 3 years after 1946, has continued since and is nearing completion.

The classification of soils is carried out on the basis of the genetic characteristics of the soil profile. Profiles are examined at points 1200 feet from each other, the points forming a regular grid or lattice pattern. The surface foot of the soil is sampled every 600 feet on a grid basis. Such close range of sampling is necessary on account of the extreme soil heterogeneity. This paper summarises the salient soil features observed in this locality.

Though many of the soils are formed from the same rock formation and under the same climate, diverse soil types are encountered. The position on the relief of the area and the soil drainage which are interconnected produce different soil micro-climates which eventually result in diverse soil types. Thus topography in this area is the chief predisposing factor in pedogenesis.

SOILS

There are two main soil groups, Black and Red, locally known as 'Regur' and 'Chalka' respectively. The latter occurring on higher situations, are essentially residual soils, eroded and leached to a greater or lesser extent, shallow to medium deep, coarse in texture and comparatively poor in colloids. The Black Soils, on the contrary, occur in lower situations and valleys, and are essentially made of products of leaching and erosion from above. These are heavy deep soils and are rich in colloids.

Red Soils : The colour of the chalka soils varies from red to various shades of brown, and depth from as little as 6″ to 4′ depending on the situation. Two major soil forming processes seem to characterise the Red soils—(i) where the breakdown of the complex is not manifest and (ii) where the breakdown is manifest by the presence of iron oxide concretions. Under the former, two types are noticed—(a) one with a single shallow horizon and (b) another with two horizons, the second horizon being a little darker and compact. The latter type (ii) is medium deep and may be divided into two sub-type classes depending on (a) the absence or (b) the presence of a zone of lime accumulation. The last type usually occurs as an alkaline and sodiumised phase.

Black Soils : In the Black soils two distinct types are recognised by the presence or absence of brown mottlings in the B horizon; the former type has excellent soil properties and drainage; and colour is usually black in the A horizon. The latter is coloured in shades of grey-black and has accumulation of clay in the B horizon. This occurs both in the normal and sodiumised phases. For the purpose of the present studies these two are treated as separate type classes.

Jallapally Soils : Survey of some recently acquired areas in the Kotgir area shows soil formations different from any described above, but rather intermediate in their characteristics between the Red and Black soils. Their genetic relationships with the other soils types are not yet determined and they are tentatively classified as Jallapally soils and kept separately in the scheme of soil classification followed. In a typical formation, the top soil is grey brown to brown, sandy with a certain amount of clay which makes it very gritty, about 9″ thick, overlying a very compact impervious B horizon which breaks into irregular clods. Below this, usually is a darker clay or clay loam layer of varying thickness. Usually, but not always, a zone of lime accumulation is found above this layer. Iron oxide concretions and some pepper sized lime nodules with a black manganous coating are sometimes seen in the profile. The thickness of these soils varies from about 2 feet to 4 feet and in rare cases to over 6 feet. The compact impervious B horizon is a typical claypan, almost completely obstructing movement of water, and appears to be due to mechanical illuviation of clay. The soil cracks, the cracks widening with depth. Salinity and alkalinity to a greater or lesser degree is usually found associated with this horizon.

SOIL TYPES AND AGRICULTURE

Classification of the soils of this estate is shown schematically in Fig. 1 along with the descriptions of characteristic profiles. Their percentage distribution in

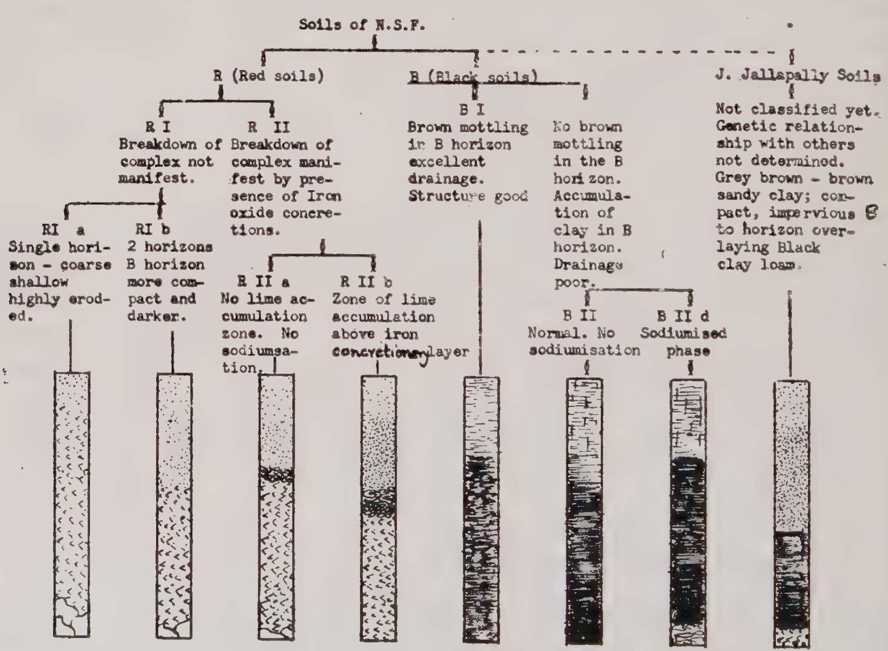
Soils of N.S.F.
R (Red soils)
B (Black soils)
J. Jallapally Soils
R I Breakdown of complex not manifest.
R II Breakdown of complex manifest by presence of Iron oxide concretions.
B I Brown mottling in B horizon excellent drainage. Structure good
No brown mottling in the B horizon. Accumulation of clay in B horizon. Drainage poor.
Not classified yet. Genetic relationship with others not determinod. Grey brown - brown sandy clay; compact, impervious B to horizon overlaying Black clay loam.
RI a Single horizon - coarse shallow highly eroded.
RI b 2 horizons B horizon more compact and darker.
R II a No lime accumulation zone. No sodiumsation.
R II b Zone of lime accumulation above iron concretionary layer
B II Normal. No sodiumisation
B II d Sodiumised phase

Fig. 1.

the surveyed areas of the estate are shown in parenthesis. Detailed chemical analysis of each type except the Jallapally soils is shown in the following pages.

The important features and agricultural properties of each type are also indicated.

SOIL TYPE—RIa

Light brown, sandy, stony, occurs on highest elevations, 6″-9″ deep; highly eroded, steeply sloping, moisture holding power and fertility very poor, overlies reddish disintegrated morrum. Levelling necessary; requires deep tillage to increase soil depth; addition of large quantity of organic matter necessary to build soil structure and to improve moisture retentivity; addition of lime necessary; requires frequent and light irrigations.

	0-6″	6-12″	0-12″
Bulk Chemical Analysis (%)			
Soil moisture			0.502
Insoluble residue			94.550
Loss on ignition			1.500
Silica soluble in KOH			8.890
Silica soluble in HCl			0.330
Total Silica			9.220
Fe_2O_3			0.760
Al_2O_3			4.000
CaO			—
K_2O			—
P_2O_5			0.015
Molecular ratios :			
Silica/Alumina			3.920
Silca/Sesqui oxides			3.510
Alumina/Iron Oxide			8.290
Physico Chemical Analysis (%)			
Sand	86.3	85.7	
Silt	2.6	6.7	
Clay	10.4	8.0	
Soil Moisture	0.502	0.507	
Moisture at sticky point	12.09	9.96	
Calcium Carbonate	1.04	0.06	
Total Salts	0.04	0.03	
pH	7.2	7.2	
Carbon	1.0	0.83	
Nitrogen	—	—	
C/N	—	—	
Available Phosphoric Acid (P_2O_5)	0.004	0.006	
Available potash (K_2O)	Traces	Traces	
Exchangeable bases (m.e. %)			
Ex. Calcium (CaO)	1.5	2.5	
Ex. Magnesium (MgO)	—	—	
Ex. Sodium (Na_2O)	0.41	0.40	

SOIL TYPE—RI*b*

Has two horizons, 'A' horizon light brown sandy loam, cloddy to single grain, the 'B' horizon little more compact, hard and prismatic, developed on situations lower than that of RIa. Moisture holding power and colloidal status better than RIa but requires essentially similar management.

	0-8″	8-17″	17-25″
Bulk Chemical Analysis (%)			
Soil moisture	1.3	3.3	2.9
Insoluble residue	91.0	81.28	81.28
Loss on ignition	2.09	3.78	3.78
Silica soluble in HCl	0.44	0.77	0.77
Silica soluble in KOH	7.5	13.5	13.5
Total Silica	7.9	14.2	14.2
Fe_2O_3	4.0	2.25	2.25
Al_2O_3	7.6	6.15	6.15
CaO	—	—	—
K_2O	—	—	—
P_2O_5	0.028	0.077	0.077
Molecular ratios :			
Silica/Alumina	5.9	3.9	3.9
Silica/Sesqui oxides	2.17	1.70	1.70
Alumina/Iron oxides	0.85	2.1	2.1
Physico Chemical Analysis (%)			
Sand	68.3	45.6	48.6
Silt	—	—	—
Clay	—	—	—
Soil moisture	1.3	3.3	2.9
Moisture at sticky point	14.4	16.2	18.4
Calcium carbonate	0.76	1.12	1.16
Total Salts	0.04	0.08	0.09
pH	7.4	7.4	7.5
Humus	0.4	0.26	0.3
Nitrogen	0.09	0.05	0.07
Carbon	0.96	0.88	1.0
C/N	10.6	17.6	14.3
Available P_2O_5	0.00305	0.0054	0.0042
Available K_2O	0.0116	0.0143	0.0123
Exchangeable bases (*m.e.* %)			
Ex CaO	7.5	12.5	12.0
Ex MgO	—	—	—
Ex Na_2O	1.1	1.37	1.6
Ex K_2O	—	—	—

SOIL TYPE—RIIa

Depth about 4′ ; 'A' horizon (0-28″) brown sandy loam, cloddy to crumby; compactness increases with depth; 'B' horizon (28″-36″) dark brown, compact; iron oxide concretions found throughout the profile but it forms a compact layer between the B horizon and the reddish disintergated morrum below. Clay about 30%, pH about 7.5, humus and organic matter poor. Ex base status fair, about 30 m.e.%; no salt or lime accumulation; drainage good, well suited for cane; addition of lime and bulky manures necessary.

	0-8″	8-18″	18-28″	28-36″	36-44″	44-54″
Bulk Chemical Analysis (%)						
Soil moisture	2.6	3.7	3.65	3.30	2.50	2.70
Insoluble residue	87.6	82.15	88.7	88.3	84.6	88.9
Loss on ignition	2.7	2.6	2.26	2.73	2.72	3.10
Silica soluble in HCl	0.26	0.36	0.28	0.31	0.33	0.30
Silica soluble in KOH	10.71	17.33	11.67	12.28	13.26	10.89
Total Silica	10.97	17.69	11.95	12.59	13.59	11.19
Fe_2O_3	3.35	2.60	3.99	4.15	5.19	3.75
Al_2O_3	2.75	8.00	4.70	3.60	3.40	4.05
CaO	—	—	—	—	—	—
K_2O	—	—	—	—	—	—
P_2O_5	0.02	0.13	0.02	0.02	0.02	0.02
Molecular ratios :						
Silica/Alumina	6.77	3.76	4.35	5.83	7.54	4.68
Silica/Sesqui oxides	3.81	3.107	2.82	3.39	3.66	2.97
Alumina/Iron oxides	1.30	4.70	1.84	1.40	0.94	1.70
Physico Chemical Analysis (%) :						
Sand	54.35	46.70	43.30	41.80	43.01	44.70
Silt	11.25	15.25	15.50	8.25	10.25	16.25
Clay	27.5	31.37	32.00	31.37	31.00	28.75
Soil moisture	2.60	3.70	3.60	3.50	2.50	2.70
Moisture at sticky point	19.00	20.20	23.00	21.50	17.40	20.30
Calcium Carbonate	1.32	1.36	1.32	1.32	1.40	1.36
Total Salts	0.137	0.155	0.155	0.166	0.166	0.182
pH	7.7	7.5	7.4	7.3	7.3	7.6
Humus	0.448	0.407	0.343	0.277	0.229	0.258
Nitrogen	0.067	0.042				
Carbon	0.50	0.56	0.74	0.47	0.47	0.37
C/N	8.35	13.3				
Available P_2O_5	0.0092	0.0091	0.0012	0.00732	0.0128	0.0090
Available K_2O	0.041	0.042	0.040	0.046	0.042	
Exchangeable bases (*m.e.* %)						
Ex CaO	19.50	24.00	22.00	24.50	23.00	22.00
Ex MgO	3.91	6.59	6.55	5.79	8.26	
Ex Na_2O	0.50	0.22	0.37	0.28	0.18	0.16
Ex K_2O						

SOIL TYPE—RIIbd

Similar to RIIa but has a zone of lime accumulation above the iron concretionary layer. Only the sodiumised phase of the RIIb type is seen in this estate and this is designated RIIbd. B horizon 10″-40″, compact hard and cloddy, rather impervious; red specks; dark grey brown sandy clay; alkaline and badly drained ; sodium saturation higher than 10% ; Ex Ca/Mg. ratios less than 5 ; salt content increases with depth.

Generally all these red soils, when dry, set into a hard and gritty mass which offers considerable resistance to tillage implements. The sandy nature makes them abrasive and wear on implements is very high. However, when moist, they become soft and easy to cultivate.

	0-10″	10-24″	24-38″	38-50″	50-72″
Bulk Chemical Analysis (%)					
Soil moisture	89.68	80.73	80.53	54.20	81.50
Insoluble residue	2.24	3.47	3.22	3.10	3.25
Loss on ignition	0.30	0.26	0.19	0.40	1.82
Silica soluble in HCl					
Silica soluble in KOH	11.43	17.62	19.38	11.54	16.56
Total silica	11.63	17.68	19.57	15.55	17.38
Fe_2O_3	2.67	3.8	3.75	27.14	2.24
Al_2O_3	4.38	9.65	10.25	6.56	6.65
CaO	0.2	1.6	1.8	5.0	0.59
K_2O	0.127	0.233	0.214	0.214	0.162
P_2O_5	0.031	0.04	0.07	0.039	0.039
Molecular ratios :					
Silica/Alumina	4.38	3.25	3.24	4.02	4.44
Silica/Sesqui Oxides	3.198	3.48	2.62	1.08	3.65
Alumina/Iron oxides	2.34	3.93	4.23	0.37	4.59
Physico Chemical Analysis (%) :					
Sand	60.18	55.30	60.20	48.50	52.7
Silt	7.5	8.7	7.5	—	20.4
Clay	26.2	32.2	32.5	—	25.6
Soil moisture	—	—	—	—	—
Moisture at sticky point	15.9	17.5	19.4	—	—
Calcium Carbonate	0.92	1.0	1.4	—	7.5
Total Salts	0.12	0.14	0.42	0.36	0.48
pH	7.8	8.5	8.1	—	8.6
Humus	0.343	0.124	0.076	—	—
Nitrogen	0.09	0.07	0.666	0.054	0.050
Carbon	0.80	0.596	0.38	—	0.46
C/N	8.80	8.50	5.80	—	9.20
Available P_2O_5					
Available K_2O					
Exchangeable bases (*m.e.* %)					
Ex CaO	7.5	11.0	8.0	—	1.0
Ex MgO	0.8	1.89	4.7	—	
Ex Na_2O	2.5	2.86	1.815	—	2.8
Ex K_2O	—	—	—	—	—

SOIL TYPE—BI

Usually about 6′ deep, but occasionally a depth of over 10′ is noticed, has excellent drainage. Surface layer has fine crumb structure; the B horizon generally below about 18″ is slightly compact, exhibiting typical shelly or lentil structure; brown mottlings increase with depth; pH 7.6—8.0; base status high; Ex Ca above 30 m.e.% upto 50 m.e.%; no salt accumulation or sodiumisation, lime about 2%; cracks on drying, weeds many. Excellent for cane; difficult to cultivate when wet and so care is necessary not to spoil the structure when wet.

	0-12″	12-30″	30-45″	45-60″
Bulk Chemical Analysis (%)				
Soil moisture	6.5	6.7	5.6	6.3
Insoluble residue	84.83	85.04	82.93	83.14
Loss on ignition	3.9	4.33	4.06	3.91
Silica soluble in HCl	0.33	0.28	0.49	0.38
Silica soluble in KOH	12.48	12.75	15.92	13.72
Total Silica	12.81	13.04	16.41	14.09
Fe_2O_3	4.7888	4.150	5.586	6.441
Al_2O_3	3.812	4.35	3.789	3.059
CaO	2.71	2.859	1.99	2.89
K_2O	0.026	—	—	—
P_2O_5	0.034	0.028	0.032	0.032
Molecular ratios :				
Silica/Alumina	5.708	5.101	7.37	7.35
Silica/Sesqui oxides	3.17	3.17	3.79	3.34
Alumina/Iron oxides	1.25	1.64	1.06	0.74
Physico Chemical Analysis (%)				
Sand	21.0	21.3	24.2	22.5
Silt	31.5	31.75	34.01	37.25
Clay	19.25	19.75	26.12	32.75
Soil moisture	6.5	6.7	5.6	6.3
Moisture at sticky point	24.1	18.8	22.2	31.0
Calcium Carbonate	2.0	1.8	2.04	2.00
Total Salts	0.28	0.31	0.37	0.79
pH	7.9	7.6	8.0	7.9
Humus	0.34	0.239	0.086	0.172
Nitrogen	0.04	0.038	0.038	0.038
Carbon	0.5	0.47	0.33	0.31
C/N	12.5	8.03	8.70	8.15
Available P_2O_5	0.0024	0.006	0.005	0.0048
Available K_2O	—	0.0116	0.0136	0.0109
Exchangeable bases (*m.e*, %)				
Ex CaO	33.0	29.0	30.5	26.0
Ex MgO	1.12	2.13	1.86	2.35
Ex Na_2O	1.109	2.13	1.86	—
Ex K_2O	0.219	0.219	0.182	0.115

SOIL TYPE—BII

Generally about 6′ deep; 'A' horizon about 2′ grey black colour; hard and compact clay loam, prismatic. 'B' horizon more compact and impervious; cracks on drying; pH 8.0 or more; salts and sodiumisation increase with depth.

Drainage precarious; vary difficult to work when wet; weeds many. Needs improvement in drainage; deep tillage is necessary to break the hard and compact B horizon; additions of bulky organic manures necessary to improve soil structure.

	0-10"	10-18"	18-28"	28-40"	40-52"	52-62"
Bulk Chemical Analysis (%)						
Soil moisture	3.55	4.7	5.04	4.9	4.5	4.7
Insoluble residue	78.94	77.19	77.32	76.95	76.78	74.8
Loss on ignition	5.99	6.96	7.03	5.54	3.84	3.74
Silica soluble in HCl	0.63	0.48	0.62	0.53	0.87	0.52
Silica soluble in KOH	16.45	16.96	18.49	20.02	20.5	19.63
Total Silica	17.08	17.44	19.12	20.55	21.37	20.15
Fe_2O_3	4.47	4.95	4.79	4.51	4.03	2.79
Al_2O_3	6.53	6.55	6.91	6.58	9.06	10.826
CaO	2.618	2.18	1.79	1.69	1.169	1.175
K_2O	0.103	0.038	0.069	0.046	0.068	0.069
P_2O_5	—	—	—	—	—	—
Molecular ratios :						
Silica/Alumina	4.44	4.18	4.706	3.647	4.005	3.265
Silica/Sesqui oxides	3.09	2.76	3.33	2.805	3.112	2.719
Alumina/Iron oxides	2.29	2.16	2.42	3.72	3.52	6.09
Physico Chemical Analysis (%)						
Sand	19.3	16.1	20.5	26.0	26.3	—
Silt	6.25	17.5	17.5	38.75	40.0	—
Clay	21.25	31.25	30.00	18.25	5.0	—
Soil moisture	3.55	4.70	5.04	5.90	4.5	4.7
Moisture at sticky point	27.0	24.6	13.9	24.9	25.2	28.25
Calcium Carbonate	2.16	1.84	1.92	1.96	2.12	2.44
Total salts	0.2	0.29	0.31	0.326	0.48	0.74
pH	7.9	7.9	8.1	8.2	8.4	7.8
Humus	0.162	0.181	0.162	0.181	0.076	0.477
Nitrogen	0.056	0.07	0.07	0.06	0.066	0.057
Carbon	0.45	0.79	0.63	0.48	0.67	0.46
C/N	8.0	11.2	9.0	8.0	9.57	7.66
Available P_2O_5	0.0067	0.0164	0.0048	0.0091	0.0103	0.0085
Available K_2O	0.0315	0·037	0.030	0.029	0.029	0.036
Exchangeable bases (*m.e.* %)						
Ex CaO	30.0	30.0	27.5	27.0	28.0	36.0
Ex MgO	6.59	5.84	5.79	6.52	7.09	8.62
Ex Na_2O	2.64	2.38	3.05	2.925	3.22	2.676
Ex K_2O	0.156	0.488	0.219	0.172	0.438	0.182

SOIL TYPE—BIId

Lying usually adjacent to the above and lower down is the sodiumised phase of the BII type; pH above 8.4 increasing to even 9.0 and above; salt increases with depth and goes as high as nearly 1%. In typical degraded conditions the whole of the B horizon, 2′-2′6″ thick is a typical 'Gley'-an absolutely impervious clay breaking into pyramidal clods, ashen grey in colour with reddish specks. Lime increases with depth. Ex Ca/Mg less than 3 and Ex Ca/Na ratio less than 5, occurring in lowest situations ; usually soil is wet when it is difficult to work the soil or use tillage machinery. Primary need to make the soil more productive is to improve laternal and vertical drainage; deep tillage and provision of drainage necessary; addition of bulky organic manures and soil amending materials necessary suitable alkali resistant varieties should be planted.

	0-6″	6-14″	14-19″	19-27″	27-34″	34-44″	44-60″
Bulk Chemical Analysis (%)							
Soil moisture	2.78	2.0	2.02	1.94	2.72	2.77	1.6
Insoluble residue	90.1	88.7	89.58	86.23	84.99	83.14	75.75
Loss on ignition	—	—	—	—	—	—	—
Silica soluble in HCl	0.38	0.34	0.22	0.86	0.46	0.56	0.37
Silica soluble in KOH	9.3	10.77	10.68	11.96	13.38	12.59	13.28
Total silica	9.68	11.08	11.90	12.82	13.84	13.15	13.66
Fe_2O_3	2.72	3.04	4.00	3.84	3.76	5.84	4.40
Al_2O_3	6.78	2.61	2.00	2.46	3.69	4.66	13.60
CaO	0.266	1.01	0.84	0.98	0.56	1.31	1.036
K_2O	0.094	0.046	0.092	0.077	0.12	0.137	0.121
P_2O_5	—	—	—	—	—	—	—
Molecular ratios :							
Silica/Alumina	2.4	7.2	9.7	8.8	6.5	4.5	5.8
Silica/Sesqui oxides	1.9	4.1	4.2	4.4	3.9	2.7	3.4
Alumina/Iron oxides	3.9	1.3	0.78	1.04	1.5	1.5	1.4
Physico Chemical Analysis (%)							
Sand	60.0	60.0	60.9	58.15	56.9	56.7	48.98
Silt	11.25	11.25	10.25	11.25	16.50	28.50	3.6
Clay	13.75	17.10	11.00	18.75	8.5	3.75	22.2
Soil moisture	2.78	2.0	2.02	1.94	2.72	2.77	1.60
Calcium Carbonate	1.8	1.84	1.92	2.2	2.04	3.6	7.8
Total salts	0.186	0.956	0.429	0.7368	0.960	0.726	0.726
pH	8.4	8.0	8.6	8.8	9.0	8.8	8.8
Humus	0.4	0.286	0.153	0.237	0.124	—	—
Nitrogen	0.067	0.06	0.074	0.035	—	—	—
Carbon	0.96	0.52	0.43	0.47	0.39	0.19	—
C/N	14.00	8.60	—	—	11.10	—	—
Available P_2O_5	—	—	—	—	—	—	—
Available K_2O	—	—	—	—	—	—	—
Moisture at sticky point	16.70	15.10	16.30	20.10	20.30	27.10	17.00
Exchangeable bases (*m.e.* %)							
Ex CaO	10.5	13.0	10.5	4.0	3.50	11.5	1.0
Ex MgO	4.12	2.17	3.57	2.46	2.6	4.05	4.12
Ex Na_2O	2.27	2.01	2.44	3.06	2.4	3.49	2.80
Ex K_2O	—	—	—	—	—	—	—

J Type : These soils described earlier are characterised by the occurrence of a hard, impervious clay pan of varying thickness. It is saline and/or alkaline to various degrees.

GENERAL

The soils of this Factory Estate, though derived from the same rocks under the same conditions and climate, occur as different types depending mainly on their situation on the external relief of the area which is highly irregular. The diversity of soil types and the extrėmely heterogenous occurrence—it is not uncommon to find more than one or two essentially different soil types within a small plot of about 8 acres—create peculiar problems of soil management. The inherent fertility of these soils appear to be partly influenced by certain unfavourable soil-water relationships which owe their origin to certain soil features themselves, and also but more to other extraneous causes; details of which are beyond the scope of this paper. Findings of this survey have been used in the planning of our research programme, and in the amelioration of soil conditions. It is clear that a different technique is necessary with each soil type and that the system of classifications followed provides a workable basis for the management of this estate. Work on the nutrient status and fertility of the different soils will be reported later.

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Paper

FORMATION OF ALKALINE SOILS AND BOGS (QUAGMIRES) IN THE NIZAMSAGAR PROJECT AREA

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In 1929, Dr. Harold Mann of Bombay Agricultural Department, who had considerable experience of problems of canal irrigation, carried out a cursory survey of the Nizamsagar tract, reached the conclusion that there was no danger in irrigating the red soils, while in regard to black soils of the tract his view was that careful investigation was necessary, before a definite plan for its conversion into wet land could be worked out. His further recommendation was that these black soils of the tract had better be classified as dry soils and irrigation on these soils made optional. Accordingly the black soils of the tract were declared as excluded soils'. This term was taken to mean that on these soils irrigation was not compulsory. His view was that the red porous soils on the upper lands, when brought under paddy cultivation would effect the lands in the lower valleys especially when these lower lands were of the heavy black soil type, would lead to the formation of alkaline soils and water-logging.

His judgment was found correct during the subsequent experience.

There are many factors, which have helped the development of water-logging and alkaline soils in parts of this tract and that this is on the increase is not being generally realised is due to the fact that most of the area is under paddy. The high price of paddy during the grow more food drive was a great stimulus, when paddy was grown on all sorts of land. It is on account of these reasons that the problem of water-logging and alkalinity remains masked under *ryots*' conditions, while the situation has become disquieting on the factory estate. The extent of alkaline and water-logged areas, as revealed during the soil survey of the factory estate is given in Table I :

TABLE I

Season	Area cropped in acres	Area determined to be water-logged & alkaline in acres	Percent
1942-43	3181	269	8.4
1943-44	3377	440	13.0
1944-45	2761	346	12.0
1953-54	5300	1060	20.0

From 1938-39 to 1949-50, soils which were manifestly unsuitable were hardly taken up at all for cane or paddy cultivation. When the area under cane was increased to 4600 acres in 1950-51 and to over 5000 acres from 1953-54 onwards and a start was made to tackle all types of soils, the full picture of the situation was revealed and it was found that soils were deteriorating and were in various stages of alkalinity and this acreage totalled to about 3200 acres or 20-25 per cent of the total land owned by the Factory.

CAUSES OF ALKALINE, WATER-LOGGED AND BOGGY SOILS ON THE FACTORY ESTATE

The Factory estate totalling 16,000 acres is not in a consolidated block. The factory estate is spread over an expanse of 26 miles. It comprises of 14 farms located at different places and separated by ryots' lands.

In the pre-project days, taking advantage of the undulating topography and the torrential spells of rains as received in the tract, 840 tanks big and small dotted all over the area, had been constructed and used for growing paddy and garden crops. The ryots—were able to see the amount of water stored in these tanks, and accordingly used the supplies carefully, but with the operation of Nizamsagar canal and perennial supply assured, and which was not based on volumetric basis as is the system in Bombay-Deccan canals, ryots of this tract were free to use it as it suited their convenience and it is this mode of utilization, which has resulted in tremendous waste during paddy growing times of the year.

The precipitation as received in the tract is not only precarious but is frequently received in heavy falls—as much as 3″ in half an hour. This results in erosion and its beating action leaves the surface soil coarse and porous due to washing down of soluble material to lower depths, which in course of time forms a hard pan. Furthermore, on account of uneven weathering of the rock, granites and gneisses, quartz veins are often found intact and serve as barrier to drainage. The canals traverse the ridges and valleys and due to porous layers there is seepage throughout the year. The percolation from the paddy fields adds to this seepage.

Now the situation is that the vertical drainage is hampered by the presence of hard pans and iron concretionery layers, and the lateral drainage is obstructed by the presence of quartz veins, by the junction where fully drained red soils and impermeable black soils meet and finally by the tanks existing in the valleys lower down. These factors are found to be the causes of water-logging and formation of alkaline and boggy soils.

THE BOGS

A bog in appearance looks a mound and when active erupts slimy material. The size of a bog may vary from place to place. It is as small as 1′ in dia mete while it could be 10 feet in diameter. At places single bogs are met with, while at others they may be seen in clusters. They could be from a few inches to 3 feet in height and as regards their depth, it was not possible to go beyond 15 feet. Whenever the underground water supply is copious, the bogs became active and multiply and slimy mud is thrown out, which on exposure gets thickened, when this water is cut off the opening of the bog gets covered with a thick crust on drying. However, if a pressure is applied, say by a human foot, the crust is broken and yellowish slimy wattle oozes out. In its latent form, the crust gets hardened and looks like a mound ashy in colour. In the vicinity of the active bogs, bull rush and other aquatic weeds are seen growing, while no vegetation is noticed on the active bog itself. However, in its latent form some salt loving grasses, do make their appearance. When the bog is very active, it has been observed that pieces of quartz stone as big as 6″ in size are brought up from layers below and thrown out. This indicates the effort of the bog to break through the barriers.

Several profiles of these bogs at various places have been studied and relative information furnished in the statement attached. In statement No. 1, data relating to morphological studies of alkaline soils and bogs are given, and No. 2 statement gives the analytical data while No. 3 statement shows chemical analysis and nature of salts associated with bogs.

Briefly stated, bogs are the extreme form of alkaline soils and are formed from impeded drainage.

SUMMARY

The occurrence of bogs in alkaline soils in the Nizamsagar Project area was examined. It was found that bog soils and wattle formations are due to sodium saturation of exchange complex, resulting in excessive volume expansion of the sub-soil. The internal pressure results in the oozing out of mud through surface crust.

STATEMENT No. I

MORPHOLOGICAL STUDIES

(a) THE ALKALINE SOILS.

These have been studied and the data relating to three typical profiles are given below.

(1) *Profile from Ahmadpur farm.*

0″ — 12″	light brown, sandy loam texture, cloddy structure. Hard when dry, lime nodules and iron concretions present.
12″ — 24″	Gray black, sandy clay texture, cloddy when dry, lime nodules and iron concretions with brown mottlings.
24″ — 38″	Gray black, sandy clay texture, cloddy when dry, lime nodules and iron concretions with brown mottlings.
38″ — 50″	Iron concretionary layer.
50″ — 72″	Yellow chopan layer, with high sodium content.

(2) *Profile from Jallapally farm.*

0″ — 18″	Dark gray brown, clay loam texture, platty structure, compact, white powder crust after 2 days of opening profile, Mn nodules found, no action of HCl.
18″ — 48″	Gray, clay loam texture, prismatic structure, compact, high total salts found.
48″ — 60″	Yellow gray, chopan or alkaline muddy, undefined structure, very high total salts.

(3) *Profile from Ekalaspur farm.*

0″ — 8″	Pinkish brown colour, sandy loam, compact (sugarcane roots seen upto 8″)
8″ — 24″	Brown colour, sandy clay texture, moist, high total salts.
24″ — 36″	Brown colour, cloddy structure, sandy clay, moist, high total salts. 36″ & below. Morrum.

(b) BOGGY AREAS.

A number of profiles from bogs were examined and their representative ones are described below.

(1) *Profile of a bog at Sathapur farm.*

This is a quagmire ripped open in summer. Fine sand and salt incrustations are seen and at places it has become patchy white.

0″ — 9″ White sandy clay, strongly effervescent with HCl, structureless, moist.
9″ — 30″ Gray clay, very moist, sticky, compact, structureless, the colour of clay deepens on exposure to light for 2 hours.
30″ Water table.

(2) *Profile of an active bog at Ahmadpur farm.*

This is an active bog (mud and slush oozing out). Bull rush seen near by.

0″ — 12″ Sandy clay, with white salt tinge, moist, strongly effervescent with HCl, structureless.
12″ — 38″ Light gray clay, very moist, highly alkaline, sticky, compact, structureless.
38″ & below Not studied.

(3) *Profile of a bog at Belal farm.*

0″ — 12″ Gray colour (silty), sandy clay, structureless, moist, strongly effervescent with HCl.
12″ — 48″ Gray colour (silty), sandy clay, structureless, moist, strongly effervescent with HCl, slush and mud entering from adjoining pits, sticky, highly alkaline, further studies impossible (depth upto 6″).
Below 48″ Not studied.

STATEMENT No. II
SALINE WATER TABLE

Several profiles were examined in the boggy areas of Belal Farm. Their location is shown in A and B series of maps attached. The sub-soil water on analysis gave the following results.

Series A

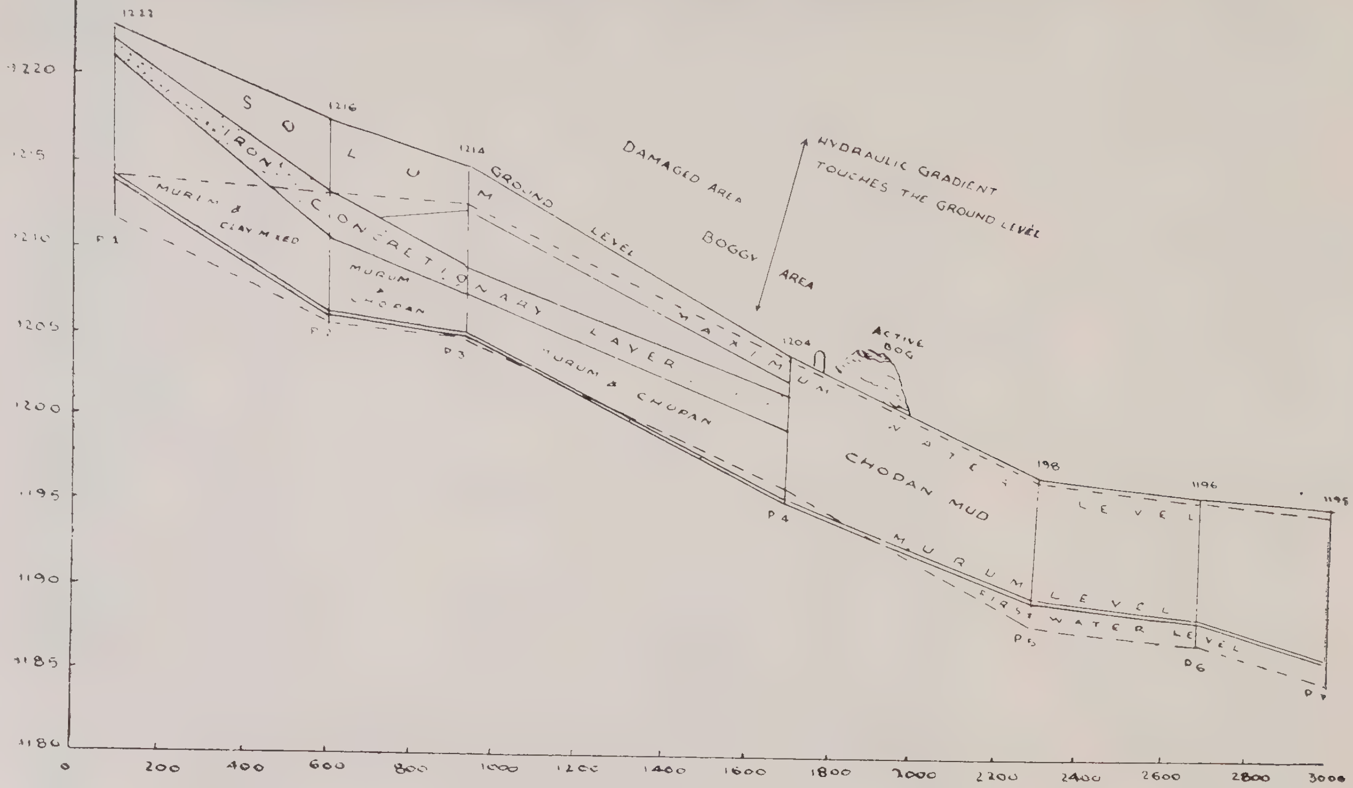
	I	II	III	IV	V	VI
1) Depth of water table	12′	10′	11′	7′	11′	9′
2) pH	9.2	8.6	9.1	9.1	9.1	8.9
3) Total salts parts per 100,000	400	40	126	80	92	90
4) Sodium Carbonate parts per 100,000	388	14.8	31.8	25.4	38.6	21.2

Series B

	II	III	IV	V
1) Depth of water table	7′	8′	5′	6′
2) pH	8.4	8.4	8.9	8.9
3) Total salts parts per 100,000	44	53	67	69
4) Sodium Carbonate per 100,000	4.2	12.7	16.9	23.3

This table shows that sub-soil water is very alkaline. pH varies from 8.4 to 9.2.

A CROSS SECTION OF THE WATERSHED FROM RIDGE TO VALLEY INDICATING THE BOGGY AREA


1222
1216
1214
1204
198
1196
1195
SOLUM
IRON
CONCRETIONARY LAYER
MURUM & CLAY MIXED
MURUM & CHOPAN
MURUM & CHOPAN
GROUND LEVEL
DAMAGED AREA
BOGGY AREA
HYDRAULIC GRADIENT TOUCHES THE GROUND LEVEL
ACTIVE BOG
MAXIMUM WATER LEVEL
CHODAN MUD
MURUM
FIRST WATER LEVEL
P 1
P 2
P 3
P 4
P 5
P 6
P 7
1220
1215
1210
1205
1200
1195
1190
1185
1180
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
2800
3000

STATEMENT No. III

Nature of salts in alkali soils and bogs. The results of the analysis of alkali soil profile (1) revealed that pH and sodium salts have increased with depth. $CaCO_3$ varied between 0.92 to 7.5%. The total salts varied with depth (0.12 to 0.48%). In the soil profile at Jallapally and Eklaspur farms, both the profiles have shown high pH and total salts besides high sodium saturation.

Samples from bogs were analysed and the data are given below.

Chemical analysis of bogs

Particulars	Bog mud	Bog crust
Silt%	19.8	20.4
Clay%	24.2	25.6
Moisture%(oven dry basis	200	—
$CaCO_3$ %	3.56	3.48
Total salts %	0.338	0.48
pH	9.1	8.6
Sodium Carbonate %	0.085	0.064
HCl Extract		
Insoluble Residue %	74.63	76.45
Loss on ignition %	2.96	2.14
SiO_2 Soluble in HCl %	0.72	0.48
SiO_2 Soluble in KOH%	20.15	20.52
Total SiO_2 %	20.87	21.00
Fe_2O_3%	2.28	3.60
$Al_2 O_3$ %	10.47	10.05
CaO %	5.00	3.700
K_2O%	0.28	0.28
Na_2O %	0.38	0.26
Exchangeable bases M.E. %		
Ex CaO	1.00	1.00
Ex Na_2O	2.87	1.20
Ex K_2O	0.20	0.30
Sodium Saturation %	75.00	50.00

Sodium saturation is higher in mud than in crust. The high carbonate in mud may be responsible for the deflocculated condition of the soils and appearance of wattle under pressure.

DISCUSSION

Mr. Bildiker remarked that sugar cane soils of the Nizam Sagar Project area as classified in the paper become hard when dry and the reason for low yields in the soils could be attributed to defective surface drainage and the impermeability of the soil.

Mr. K. L. Khanna presented the following paper.

Paper

A SCHEME FOR THE CLASSIFICATION OF SOILS IN THE SUGAR BELT OF BIHAR

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INTRODUCTION

A survey of the sugarcane growing soils in the alluvial tracts of Bihar State was begun in the year 1940 in connection with developmental work on this crop, which led to their demarcation into four broad divisions based on variations in climate and nature of parent alluvium [Prasad et al (4)]. Bhattacharya and co-workers (1) further sub-divided the soils into lower levels of classification viz., types and phases. A stage has now been reached when the accumulated data can be arranged in a coherent system so as to include, on the one hand, all known soils obtained under the specific pedogenic factors operating in the tract and to fit them into the world system of classification on the other, local terminology being translated into international nomenclature for easy appreciation by workers everywhere. An attempt at provisional classification was made by Bhattacharya and others (3) which aimed at linking up the various levels of classification, from the highest (soil order) down to the lowest (phase). In the present communication, the scheme has been further elaborated and takes into account the mineralogical composition of the clay fraction besides linking up the different levels of classification. The scheme (briefly described below) would include all known soils of the tract and also fit in the world system.

THE SCHEME

Classification levels	*Basis of differentiation*
(1) Soil Order :	Presence or absence of genetically related horizons
(2) Soil Class :	Silica-sesquioxide ratio of clay fraction to the soil
(3) Soil Division :	Variations in climate and nature of parent alluvium, the latter being predominant
(4) Soil Category :	Age of deposition of alluvium as indicated by the number of layers formed in a profile
(5) Soil Series :	Characters of sub-soil material
(6) Soil Type :	Texture of surface layer
(7) Soil Phase :	Important deviation in surface characters from those of normal type

The different levels of classification, as shown above, have been briefly discussed below *vis-a-vis* the sugarcane soils of Bihar.

(1) *Soil Order* : The soils of the sugar belt of Bihar lie on the vast Indo-Gangetic-Brahmaputra plain and are composed mainly of transported alluvium brought down by the rivers. The soils are marked by complete absence of genetically related horizons. Soil characters are chiefly determined by the nature of parent alluvium, the influence of climate being less marked. The whole tract thus comes under Azonal Order with reference to the world system of classification.

(2) *Soil Class* : The clay fraction is the most reactive portion which holds the nutrient elements and determines the physical and chemical properties of the soil. In fact many problems, especially those relating to genesis and profile characteristics, cannot be successfully solved without a knowledge of the composition of the clay fraction. The silica-sesquioxide ratio of the clay is a convenient attribute providing an approximate indication of the general characteristics of a soil. Thus according to Robinson (5) siallitic clays can be distinguished by their high or medium silica-sesquioxide ratios and ferrallitic clays by their moderate or low ratios and he has suggested a ratio of 2.0 as the critical line of demarcation between the two. The two kinds of clays on either side of the line will have different chemical and physical properties and may necessitate different soil management schedules. Two soil classes have accordingly been formulated here, viz., class A and class B, having silica-sesquioxide ratio above and below 2.0 respectively. Both classes occur in the Gangetic-Brahmaputra plain, class A being represented by soils of the Bihar Sugar Tract [Bhattacharya et al (2)] and class B by the soils of Bengal and Assam [Ukil et al (6)]. At this level of classification, the Bihar sugarcane soils thus come under class A.

(3) *Soil Division* : This is based on variations in the nature of parent material and climate, primarily the former. Four divisions have been recognized, viz., (*i*) Non-calcareous, (*ii*) Calcareous, (*iii*) Heavy Clay, and (*iv*) Sone alluvium [discussed at length by Prasad et al (4) loc. cit.].

(4) *Soil Category* : This is based on the age of parent material, viz., (*i*) Recent deposition, (*ii*) Young alluvium, and (*iii*) Older alluvium. The recent depositions category exhibits multiple horizons with alternate layers of silt and sand, each layer being clearly differentiated from the other in colour, texture, compaction etc. The soils under the young alluvium category show three to four layers, the top layers usually showing diffused boundaries and lower layers being marked by clear zonations. Older alluvium profiles exhibit two to three layers with diffused boundaries. Morphological features of typical profiles belonging to each of the three categories under the non-calcareous soil division are presented below by way of illustration.

Locality : Bargarhawa (Narkatiaganj Reserved Area, Champaran).
Soil Division : Non-calcareous.
Soil Category : Recent depositions.

Depth	*Description*
0″- 7″	Brownish grey, light texture, loose compaction, layer differentiation clear.
7″-18″	Light grey, medium texture, moderate compaction, layer differentiation marked.
18″-36″	Whitish brown, sandy texture, very loose, layer differentiation well marked.
36″-38″	Grey, medium texture, compact, layer differentiation marked.
38″-60″	Whitish brown, sandy texture, very loose, layer differentiation well marked.
60″-62″	Grey, clayey texture, compact, layer differentiation clear.
62″-72″	Brown, sandy texture, very loose, layer differentiation clear.

Locality: Rajwatia (Bagaha Reserved Area, Champaran).
Soil Division : Non-calcareous.
Soil Category : Young alluvium.

Depth	*Description*
0″-18″	Dark grey, heavy texture, medium compaction, diffused layers.
18″-36″	Brownish grey, heavy texture, medium compaction, less diffused layers.
36″-56″	Light grey, light texture, loose compaction, layer differentiation clear.
56″-72″	Grey, medium texture, medium compaction, layer differentiation clear.

Locality: Shankerpur (Riga Reserved Area, Muzaffarpur).
Soil Division : Non-calcareous.
Soil category : Older Alluvium.

Depth	*Description*
0″-19″	Light, grey, light texture, loose compaction, no horizon differentiation.
19″-40″	Dark grey, medium texture, medium compaction, no horizon differentiation.
40″-72″	Grey, heavy texture, very compact, no horizon differentiation.

(5) *Soil Series* : Series differentiation of alluvial soils, which do not exhibit a sequence of genetically related horizons, presents much difficulty. These soils consist of geological depositions differing widely in characteristics between layers. An infinite number of series would thus spring up if all the difference in the occurrence of such layers is taken into account, thereby defeating the very purpose of classification. As such, following the recommendations of U.S.D.A. (7) for alluvial soils, series differentiation has to be based on the texture of the material of the sub-soil other than that of the ploughed top layer and that of the deep sub-stratum. For soils of the Bihar Sugar Belt, it has been found best to take the following characteristics of the sub-soil into consideration while making series differentiation:—

(a) depth, (b) texture, (c) permeability, and (d) concretion zones. The limits set in respect of these criteria are shown below :

(a) *Depth of the sub-soil.*
 (*i*) Shallow-between 0″-30″.
 (*ii*) Moderately deep—between 30″-50″.
 (*iii*) Deep—more than 50″.

(*b*) *Texture of the sub-soil.*

- (*i*) Light surface soil underlain by light sub-soil.
- (*ii*) Light surface soil underlain by medium to heavy sub-soil.
- (*iii*) Medium to heavy surface soil underlain by light sub-soil.
- (*iv*) Medium to heavy surface soil underlain by medium to heavy sub-soil.

(*c*) *Permeability of the sub-soil.*

- (*i*) Permeable : Abundant iron mottlings and brown patches.
- (*ii*) Moderately permeable : Iron mottlings and brown patches present with some green specks which turn brown on exposure to air.
- (*iii*) Almost impermeable : Abundant green patches turning brown on exposure to air.

(*d*) *Concretion zone of the sub-soil.*

- (*i*) Shallow—between 0″-30″.
- (*ii*) Moderately deep—between 30″-50″.
- (*iii*) Deep—more than 50″.

Besides depth, nature of concretion (whether calcium carbonate or iron) has to be indicated.

Profiles showing the same sub-soil characteristics have to be classed under one series to be named after the place of origin in accordance with the system followed by U.S.D.A. (7). A short description of the sub-soil characteristics may conveniently replace names to specify series and such a procedure would be more useful so far as workers in other parts of the country are concerned. In this connection a normal or key series in each category has to be ascertained and may be named as series A. Deviations in respect of any sub-soil characteristics are then to be adequately described and divergent profiles placed under series B, C and so on.

(6) *Soil Type* : Soil type is a sub-division of soil series based on the texture of surface soil. The soil type name consists of the series name *plus* the textural class name determined primarily by the upper part of the soil (generally the cultivated surface layer of arable soils). Thus under Pusa series [Bhattacharya et al (1)] the major soil type recognised is sandy loam, other types found being silty loam and clay loam.

(7) *Soil Phase* : The soil types may finally be sub-divided into phases depending on important deviation in surface characters from those of the normal type. The common bases for differentiating among phases within a soil type may include such factors as variation in soil relief, degree of erosion, depth of surface soil, salinity, soil reaction, etc., which have not influenced soil morphology significantly. In calcareous soils of the semi-arid zone, Bhattacharya et al (1) have defined phases on the basis of depth of surface soil and salinity. For non-calcareous soils of the semi-humid zone, the basis of differentiation has been the reaction of the surface layer.

AN ILLUSTRATION OF THE SCHEME

As an illustration of the proposed scheme of classification a typical profile from Motipur area (Calcareous division) with the undernoted morphological features may be taken.

Depth	*Description*
0″-10″	Light grey, light texture, loose compaction, diffused layers.
10″-26″	Grey, light texture, moderately compact, some brown mottlings present, diffused layers.
26″-50″	Grey, medium texture, compact, abundant brown mottlings, calcium carbonate accumulation showing *kankars* (concretions), layer differentiation clear.
50″-68″	Dark grey, heavy texture, more compact, brown mottlings and brown patches present, layer differentiation very pronounced.

The texture of the surface layer is sandy loam and the soluble salt content in the surface layer is 257 mg. per 100 gm. of soil.

A soil, as represented by the above profile, can be classified as follows :—

Soil Order : A zonal.
Soil Class : A. (SiO_2/R_2O_3 of clay more than 2.0).
Soil Division : Calcareous.
Soil Category : Young Alluvium.
Soil Series : Light grey surface soil of light texture underlain by moderately deep, medium to heavy textured sub-soil of good permeability and showing lime concretion at moderate depth.
Soil Type : Sandy loam.
Soil Phase : Normal depth and saline phase.

IV. SUMMARY

A system of soil classification based on real and accessible soil characters has been formulated which includes all known soils of the sugar growing areas of Bihar State and also fits in the world system of classification.

V. ACKNOWLEDGMENT

The work was carried out as a part of the Sugarcane Research Scheme in Bihar being financed jointly by the Government of Bihar and the Indian Central Sugarcane Committee to whom grateful thanks are due.

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DISCUSSION

Mr. N. K. Das stated that emphasis should be laid on the category instead of soil order level. He also remarked that the procedure of soil classification as given in the paper, was likely to create a good deal of confusion in fixing the soil types.

In the absence of the author, the Chairman presented the following paper.

Paper

SUGARCANE SOILS OF WEST BENGAL

S.K. Mukerji

Agricultural Chemist, West Bengal, India.

West Bengal has an area of over 50,000 acres under sugarcane, producing on an average 15 to 20 tons of cane per acre. The quality of cane produced is good. The average recovery in the only mill of West Bengal during 1954-55 was 10.99; commencing from 10.5 during November to 10.5 during April with a peak recovery of 11.17 during the month of February.

Besides the mill area, sugarcane is grown all over West Bengal. In considering soils, tracts where sugarcane is grown in an area of over 300 acres in a Union, have only been considered. The Union is a unit having about 5000 acres of cropped land. Their location and soil associations have been given in Table I.

The soils which grow sugarcane fall mainly into the soil association called Ganga Riverine, Vindhya Riverine, Lateritic Colluvials and Buxa Riverine Lands.

The main characteristics of these soil associations have been given in Table II.

The largest area which grows sugarcane is found on the Gangetic Riverine soils. These soils are calcareous, permeable and have properties to retain moisture in the subsoils. They are easy to work with. They do not suffer from water-logging for long periods. The water drains away as soon as the rains stop. This type of soil is similar to the one found in the *Bhat* areas of Gorakhpur, U.P. (1 & 3) The climatic conditions are ideal for growing sugarcane. In fact the two sugarcane crushing mills, one of which has stopped working, draw their cane from this tract.

TABLE I

SHOWING THE POCKETS WHERE SUGARCANE IS GROWN

District	Police Station	Union	Area under Cane in acres	Soil Association
Nadia	Karimpore	Hogalberia	366.20	Ganga Riverine
	Kaliganj	Kaliganj	1597.37	-Do-
		Plassey	630.11	-Do-
	Nakasipara	Bikrampore	345.35	-Do-
Mursidabad	Beldanga	Konnagar	327.63	-Do-
		Rampara	805.44	-Do-
		Ramnagar	813.40	-Do-
	Suti	Nurpur	346.71	-Do-
	Farakka	Arjunpur	325.99	-Do-
	Samserguni	Kanchantala	455.49	-Do-
	Bharatpur	Jagan	419.98	Vindhya Riverine
Birbhum	Nanoor	Charkalgram	735.44	Vindhya Riverine
		Thupsara	433.67	Do. Colluvial Soil
Burdwan	Kanksa	Bidbihar	316.12	Lateritic Wash
	Jammuria	Jatejonaki	310.25	Do.
Dinajpur	Kushmandi	Matigaon	325.10	Not known
Malda	Englishbazar	Amrity	357.98	Ganga Riverine
Jalpaiguri	Kumargram	Kumargram	336.26	Buxa Rivernine

TABLE II

Particulars	Ganga Riverine Lands	Vindhya Riverine Lands	Latteritic Colluvials	Buxa Riverine Soils
Profile development	Immature	Immature to slightly mature	Immature	Immature
Colour of the soil	Olive to light olive brown 5y4/4 to 2.5y5/4	Greyish brown	Red	Olive grey
Concretions	Nil	Small mustard like nodules at a depth of 3 ft.	Occasional dolomite throughout the profile	None.
pH	7.0-8.5	5.4-7.0	5.5-7.0	7.0-8.5
Lime as $CaCo_3$	1-10	Nil	Nil	1-10
Sesquioxide	Immobile	Slightly immobile	Immobile	Immobile
Clay percent	Average to low	Average to low	Average to high	Low
Sol. Salts	Low	Low	Low	High
Lime saturate	Free lime	About 80%	About 60%	Free lime
Drainage	V. good	V. good.	V. good	Good
Texture	Light top Light bottom	Light top Light bottom	Medium top Medium bottom	Light top Light bottom

The chemical, mechanical and general descriptions of a typical profile from each soil association are given in Tables III to VI.

TABLE III

SHOWING MECHANICAL, CHEMICAL AND GENERAL COMPOSITION OF GANGA RIVERINE SOIL

	Percentage on oven dry basis			
Depth in inches	0-12	12-35	35-40	40-48
Coarse Sand	0.18	0.17	0.32	0.22
Fine Sand	58.9	55.4	86.4	45.18
Silt	32.15	35.75	10.5	43.9
Clay	10.65	10.20	4.95	10.0
pH	8.18	8.33	8.68	8.40
Organic Carbon	0.57	0.35	0.13	0.40
Nitrogen	0.033	0.045	0.01	0.028
Sesquioxide	9.7	11.4	6.0	11.55
Fe_2O_3	4.08	4.56	2.72	5.0
Al_2O_3	5.48	6.70	3.12	6.39
CaO	5.39	5.3	4.92	5.53
P_2O_5	0.14	0.14	0.16	0.16
K_2O	0.36	0.39	0.35	0.34
T.S.S.	0.058	0.057	0.042	0.064
N/2 acetic acid Sol. bases m.e. %	184.4	191.6	165.2	186.8
N/2 acetic acid Sol. CaO m.e. %	156.6	156.6	145.6	161.6

TABLE IV

SHOWING MECHANICAL, CHEMICAL AND GENERAL COMPOSITION OF VINDHYA RIVERINE SOIL

	Percentage on oven dry basis			
Depth in inches	0-12	12-21	21-28	28-48
Coarse Sand	19.0	4.77	17.12	1.0
Fine Sand	47.0	53.38	23.78	67.8
Silt	15.6	16.75	23.40	11.0
Clay	15.7	22.4	31.80	17.6
pH	6.64	6.75	6.92	6.87
Organic Carbon	0.28	0.13	0.20	0.08
Nitrogen	0.035	0.026	0.029	0.015
Sesquioxide	5.67	11.05	14.72	9.89
Fe_2O_3	2.32	4.24	5.76	4.24
Al_2O_3	3.35	6.81	8.96	5.65
CaO	0.28	0.51	0.58	0.46
P_2O_5	0.045	0.039	0.054	0.07
K_2O	0.17	0.326	0.345	0.258
T.S.S.	0.017	0.017	0.023	0.020
N/2 acetic acid Sol. bases m.e. %	6.34	10.56	14.40	10.56
N/2 acetic acid Sol. CaO m.e. %	4.24	6.78	9.12	7.0

TABLE V

SHOWING MECHANICAL, CHEMICAL AND GENERAL COMPOSITION OF LATERITIC COLLUVIAL SOIL

Percentage on oven dry basis

Depth in inches	0-14	14-27	27-48
Coarse Sand	38.17	7.33	31.71
Fine Sand	28.40	23.07	21.45
Silt	12.53	37.85	11.15
Clay	19.58	29.60	33.00
pH	5.35	5.4	6.3
T. S. S.	0.023	0.023	0.023
Organic Carbon	0.456	0.376	0.218
Nitrogen	0.063	0.044	0.023
Sesquioxide	5.28	7.46	18.34
Fe_2O_3	2.60	4.08	12.76
Al_2O_3	2.68	3.38	5.58
CaO	0.213	0.212	0.258
P_2O_5	0.041	0.054	0.078
K_2O	0.26	0.27	0.21
N/2 acetic acid Sol. bases m.e. %	5.72	5.52	6.60
N/2 acetic acid Sol. CaO m.e. %	2.40	2.76	4.48

TABLE VI

SHOWING MECHANICAL AND GENERAL COMPOSITION OF BUXA RIVERINE SOILS

Percentage on oven dry basis

Depth in inches	0-6	6-20	20-31	31-41	41-49
Coarse Sand	1.19	1.41	0.68	24.82	2.62
Fine Sand	70.66	77.47	29.72	65.72	13.21
Silt	20.73	15.48	59.79	6.01	71.70
Clay	5.68	3.31	8.36	2.60	11.10
pH	6.1	7.1	7.8	7.8	8.0
T. S. S.	0.08	0.54	0.44	0.53	0.41
Organic Carbon	0.453	0.139	0.194	0.09	0.24
Nitrogen	0.068	0.014	0.021	0.008	0.027
Sesquioxide	10.25	12.44	15.95	9.26	18.51
Fe_2O_3	4.7	4.92	6.10	4.44	6.88
Al_2O_3	5.55	7.52	9.85	4.82	11.63
CaO	0.27	0.56	1.56	1.16	1.48
P_2O_5	0.13	0.05	0.03	0.05	0.04
K_2O	0.52	0.11	0.44	0.22	0.48
N/2 acetic acid Sol. bases m.e.%	4.2	19.4	59.8	38.4	59.6
N/2 acetic acid Sol. CaO m.e.%	2.4	16.8	47.6	36.8	47.6

Next largest area under sugarcane is found on the Vindhya Riverine tract. This refers to the areas which have been formed due to alluviation by rivers, originating in the Chota Nagpur Plateau which is the eastern extension of Vindhya Range of Central Indian hills. These are good arable soils with good permeability and grow good quality cane with fair yield provided during summer irrigation facilities can be made available. With the excellent facilities of irrigation now provided by the Damodar and Mor Canals, this area has become eminently suitable for growing sugarcane. The soils of the area resemble the type of soils generally met with, in the *Bangar* areas (Sardarnagar, Baitalpur, Deoria etc.) of the Gorakhpur District U.P. (1 & 3).

Next in order is the area which has red soils, frequently with *morrum* in deeper sub-soils formed in the river valleys of the laterite tract. Seepage of water from hillock provides irrigation for cane cultivation. The yield is fair and quality good. Though the soils become sticky and plastic when wet, unlike clays they remain porous. This type of soils responds very well to manuring. Ratoons, however, are very poor due to low inherent fertility of these soils. These resemble the red lands (2) which grow sugarcane in tropics. With the completion of the proposed Kangsabati irrigation project, this area may assume great importance for growing sugarcane. The rainfall is about 60-70 inches per annum.

The last tract comprises of the Buxa Riverine area in North Bengal. The Buxa rocks consist of pure dolomite with occasional pockets of calcite. The streamlets originating in these rocks, bring down innumerable large boulders of dolomite, which get powdered in transit and are deposited in the foothills of the Himalayas. The soils being subjected to a rainfall of about 140 inches have developed some acidity on the surface, but the sub-soils still retain calcium carbonate and are mildly alkaline. Soils are porous with excellent moisture status. Floods are of short duration. Sugarcane grows very well similar to what one finds in the Chhitauni region of Deoria district in U.P.

REFERENCES

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3. Proc. 15th Ann. Conv. Sug. Tech. Asson. India. 1946.

In the absence of the author, the following paper was taken as read and was discussed together with the next two papers presented by Dr. Patel.

Paper

THE EFFICIENT USE OF PHOSPHATIC FERTILIZERS ON ACID, PHOSPHATE FIXING SUGARCANE SOILS

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INTRODUCTION

In this paper an effort is made to present a discussion of the main results obtained in a series of experiments conducted by the author in 1953-1954 at the Imperial College of Tropical Agriculture in Trinidad. These experiments were designed to study the availability of phosphate (P_2O_5) when applied in various forms, to plant cane, and also the placement methods for phosphate fixing acid soils. Also included in the tests was the influence of lime ($CaCO_3$) on : (i) the phosphate fixing properties of the soil, (ii) the availability of phosphate dressings, and (iii) the rate of phosphate uptake by the sugarcane plant. The cane variety used for all the experiments was B 37—172. The drum-test technique offered itself as the most suitable for these investigations under rigidly standardized and closely controlled conditions. Treatment effects were judged by statistical analysis of tiller counts, shootlength measurements, yield weights and phosphate concentration in the plant, leaves and juices. Each of the experiments involved has been fully described in a series of six articles and the reader may refer to that literature for further information (1) From these studies, three basic principles emerged which are fundamental for the proper understanding of the effect of phosphate dressings when applied to acid phosphate fixing soils. It was proved that in general the efficiency of a phosphate dressing depends on :

(*a*) the creation of a limited but sufficiently large contact area betwee the active surfaces of phosphated soil-particles and the root-hairs ;

(*b*) the achievement and maintenance of a sufficiently high phosphat status of the soil in the contact area ; and

(*c*) the improvement of conditions controlling the absorption mechanis of the root-hairs.

The various aspects of these three principles will be discussed further.

PHOSPHATE AND PHOSPHATE FIXATION IN SOILS

In each soil there is a certain amount of "total phosphate" which consists of organic and inorganic compounds. The insoluble organic compounds are mainly accumulated in the top of the soil and are located in the residues of the macro and micro bio-sphere and in the living tissues of the latter. The inorganic phosphate is found in primary and secondary phosphate minerals dispersed through the soil and in chemical combination with cations which are mostly precipitated or absorbed by the soil. Unfortunately, most of this phosphate is soluble in water only to a slight extent under conditions normally prevailing in acid soils. However, minute quantities from this "total phosphate reserve" will go into solution and circulate in the soil moisture at a very low concentration which may vary between 0.2 and 0.01 mgm. P_2O_5 per litre. It is from this source of dissolved phosphate that plants may draw their requirements directly. The quantitative relationship between the phosphate ions in the soil moisture and the "total phosphate reserve" is very much complicated by the variable and complex nature of the latter, and is further obscured by the influence of many other soil factors. Therefore, it should be realised that the concentration of phosphate ions in the soil solution is the result of a multi-factorial equilibrium between the solid and liquid phases of the soil. This equilibrium is dynamic and it may shift continuously with location and time. In a general manner, however, it can be stated that the more a particular soil tends to bind phosphate and the lower is its "total phosphate reserve", the slower will it release phosphate ions into the soil moisture. Likewise, it follows that for soils with a high phosphate binding capacity, larger amounts of phosphate have to be added with a view to saturating the phosphate binding forces of the soil and shifting the final equilibrium towards higher concentrations of phosphate ions in the soil moisture. The process by which water-soluble phosphate is rendered insoluble by the soil is known as "phosphate fixation". This term, however, is rather deceptive, as it stands for a number of fixation reactions which are essentially different in nature and practical outcome. Consequently, it should be well appreciated that phosphate which has been "fixed" in the soil is *not* necessarily "locked-up" and thus rendered totally unavailable to the plant roots. Plants are not merely dependent on nutrients circulating in the soil solution in a passive way, but they are capable of exerting influence, by excretional activities of the roots, on the ion-exchange conditions prevailing in the moisture-film which separates the active surfaces of root-hair and the adjoining soil-particles. In other words, the plant-roots may enter into an active competition with the phosphate binding forces of the soil and thus may be able to mobilise and absorb larger quantities of phosphate from the "total phosphate reserve". The following experimental findings may illustrate the importance of the various factors involved in the process of phosphate uptake by the cane plant from phosphate dressings applied to acid soils. These factors will be discussed under the three fundamental principles already mentioned.

THE CONTACT AREA BETWEEN PHOSPHATED SOIL AND ROOT-HAIR SURFACE

The contact area between phosphated soil (or phosphatic fertilizers) and the active root-hair surface should be so much enlarged that a sufficient portion of the active root surface might participate in the process of phosphate absorption. It was proved on the two acid soils that superphosphate dosages dissolved in water and intimately mixed with a considerable volume of soil were more effective than the same dosages "placed" in powdered form in a thin layer of 6×6 sq. inches close underneath the seedpiece.

Thus it will be observed that the phosphate, exposed to the maximum possible extent to the fixing capacity of a phosphate-deficient soil, is more effective and better absorbed by the plant than the phosphate which is placed in a restricted area where phosphate fixation is greatly eliminated and where contact is established only for a short while with the roots passing by. This would apply specially to the period when rapid aerial development of the cane plant demands an increasing supply of phosphate, which can only be met adequately by the larger volume of phosphate enriched soil. Phosphate fixation is not effective if the fixation takes place only in that part of the soil where the majority of the absorbing roots are found. In this respect it should be remembered that, contrary to many other nutrients, phosphate must be regarded as an extremely immobile nutrient in this type of soil. It will not spread or move farther than a few inches from the spot where it is applied. As there is no appreciable chemotropic movement of the roots either, in the absence of diffused H_2PO_4-ions the roots may encounter the phosphated spots only by chance. For this reason it is imperative to reduce this element of chance as much as possible, by spreading the phosphate in such a way as to provide for the newly growing roots coming in contact with P_2O_5 to the maximum possible extent. This point was also demonstrated by another test as summarised below :

In a drum experiment two different phosphate placements were compared. In one lot of drums, dissolved superphosphate was mixed with the soil which was planted with cane immediately afterwards. In a second lot, cane was planted at the same time but powdered superphosphate was applied to the soil surface as late as 13 weeks after planting. At this stage it was found that growth, tillering and phosphate content of the leaves were significantly better in the first lot. However, after the phosphate application in the second lot, growth and tillering improved rapidly and equalled those of the first lot in a few months' time. The difference in the phosphate content of the leaves, which was very striking at the beginning, had also levelled off after 2 months.

This surprising result can be explained by the fact that encouraged by a moist mulch layer which protected the soil surface, the canes started to develop a dense mass of roots near and at the soil surface. The copious growth of new roots right in the thin phosphated layer led to a tremendous expansion of the contact area between roots and the phosphated soil—resulting in an accelerated rate of phosphate uptake by the plant at a moment when it was most needed for further aerial development. If, however, under field conditions, heavy rains had washed away the greater part of the surface dressing, or if drought had inhibited the development of roots in the phosphated top layer, the results of the trials would have been the reverse. Thus it is obvious that conflicting experimental results may be obtained if the relation between the actual location of the phosphate and the formation of roots is not taken into account.

THE ACHIEVEMENT AND MAINTENANCE OF A HIGH PHOSPHATE STATUS

The absolute phosphate status of the soil is also important when judging the effect of phosphate applications and phosphate fixation. It has been pointed out already that in case the phosphate status of a soil is very low and its phosphate binding capacity strong, it will be impossible for the plant to release and absorb phosphate at a sufficiently high rate. Small amounts of water soluble phosphate added to such a soil will be very firmly retained by the soil because its phosphate fixing capacity remains unsaturated. It needs larger dosages of phosphate to neutralise this phosphate fixing tendency of the soil, and to ease the competition between the phosphate retaining soil surface and the phosphate absorbing root-hair surface.

It has already been mentioned that in the comparison between the effect of largely dispersed and very much concentrated phosphate placements, the latter was observed to be less effective. A comparative study with relatively low phosphate dressings, on one hand, and dispersal of a certain phosphate dosage through a large volume of soil (dispersed within the top 6 inches of the soil), on the other, reveals that the latter treatments lead to better results in the descending order of the volume of the soil used for dispersal. These findings demonstrate that if small phosphate dosages are "diluted" with large volumes of soil, the chemical phosphate-binding properties of the soil are accentuated to the disadvantage of the phosphate absorbing capacity of the roots—shifting chemical fixation in the direction of physiological fixation. For this reason it is quite unnecessary to raise the phosphate status of the larger part of the total rooting medium with large quantities of phosphatic fertilizers. It is sufficient to raise the phosphate status in a limited but selected part of that rooting medium, provided an adequate contact area with the root-hair surface is ensured.

The phosphate status of the soil is difficult to assess, but it may be gauged by its "available phosphate" value obtained by any of the conventional soil extraction methods. Although such a value can never be assumed to be identical with that part of the "total phosphate" which is readily assimilable by the plant, we may expect that both "available" and "assimilable" phosphate will increase when additional phosphate is incorporated in the soil and the phosphate fixing forces of the soil are diminished. Under standardized conditions a correlation can be established between "available phosphate" in the soil and crop response for any of the acid soil types separately, and a level of adequacy can be determined.

In all experiments the "Truog extraction method" was used to gauge phosphate status of the soil. Large batches of a red ferruginous clay were phosphated to various degrees by mixing the dried soil with phosphate solutions of increasing strengths. In this way soils with six different phosphate levels were prepared, each being well defined by a distinct and reproducible "Truog value" for "available phosphate". The relation between added P_2O_5 and "available" P_2O_5 could be represented by a straight line based on a highly significant regression. The soils were used in a drum test so that each cane plant could explore about 240 lbs. of (air-dry) phosphated soil. Leaf analysis, millable cane yields and juice analysis gave indications that for the well-aerated phases of this soil type a "Truog value" of 40 p. p. m. would be adequate ; where as, for shallow phases a "Truog value" of about 75 p.p.m. should be aimed at.

Experimental evidence also proved that the effectiveness of a given phosphate status did not decline when the soil was exposed to an artificial "ageing" process simulating a four months' period of tropical weathering.

A large sub-batch of a phosphate fixing acid soil was treated with a phosphate solution and subsequently exposed to a process of alternating wetting and intensive drying for four months. A second sub-batch was phosphated in exactly the same way at the end of that period. The phosphate status so produced was inadequate for yielding an optimum crop when the soil was planted with a phosphate sensitive indicator plant. It was seen that crop weights and phosphate contents were the same for both treatments, showing that the physiological level of assimilable phosphate remained the same, although the ageing treatment produced a somewhat higher degree of chemical fixation as measured by the Truog method.

It appears that the residual effect of a superphosphate dressing on strong phosphate fixing acid soils is very satisfactory, and that it is possible by means of repeated dressings throughout the cycle to raise and maintain the phosphate status of the top soil to the desired level, provided that losses of P_2O_5 through surface washing and removal by the crop are taken into account.

IMPROVEMENT OF CONDITIONS CONTROLLING THE ABSORPTION MECHANISM

Although little is known about the mechanism of phosphate uptake itself, it may be assumed that cane varieties differ in their ability to explore the phosphate sources of the soil because of genotypical and phenotypical differences of the root systems. Cane varieties may differ also in their susceptibility to certain harmful soil factors which adversely affect the function of the root hairs. Poor aeration of the rooting medium is one of these harmful factors. Therefore, it may be borne in mind that on soil phases with poor structure and drainage a higher phosphate status should be maintained; and on deep, well aerated soil phases lower phosphate levels will prove to be adequate. Excessive soil acidity is another extremely harmful factor, as was observed in these experiments. It has been demonstrated by Van Honert that the uptake of monovalent H_2PO_4-ions by cane in water cultures was increased six times between pH 7.5 and pH 4.5—being maximum at the lower one. However, it is a well observed fact that cane roots can be severely damaged when in contact with highly acid soil presumably through the toxic effect of free trivalent ions like aluminium and manganese. The colloidal semi-permeable root membranes seem to lose their selective function and toxic amounts of these trivalent ions enter the plant. The roots react in a protective way sealing off the tips, a process which results in a knotted root development. The symptoms disappear when the soil is properly limed. The beneficial effect of lime on growth of cane, uptake of phosphate and clarification of juices was the most outstanding feature in all experiments.

In one experiment, cane yield after 4 months growth and also phosphate uptake by the cane were compared for unlimed and limed batches of an acid sugarcane soil. For liming 10 gm. of calcium carbonate per kg. of air-dry soil was used. The phosphate dressing used in both the treatments was 37.5 gr. superphosphate (40%) per plant. This quantity was mixed in powder form with the top 6 inches of the soil. The lime treatment caused an increase in the weight of plants by 9 percent and doubled the intake of phosphate.

As the supply of phosphate in both the treatments was abundant, the action of lime cannot be explained by an increase in the amount of assimilable phosphate in the soil. This can be ascribed only to an improved functioning of the roots.

SUMMARY AND RECOMMENDATION

In the foregoing, it has been explained that the response to any phosphate dressing below the optimal dosage depends on : the concentration of the phosphate in the soil, the contact area between the absorbing root surface and phosphated soil particles, and on the proper functioning of the roots. In order to obtain the greatest rendement of a phosphate dressing the three factors should be combined correctly. To this end the following general recommendations are suggested:—

(*a*) Avoid any surface application of phosphate, unless a lasting mulch layer is maintained during the first four months to protect the underlying phosphated top layer against surface wash and the active surface roots against desiccation and final death.

(*b*) The top 12-18 inches of soil should be conditioned in such a way that optimal aeration and constant moisture supply in that layer are ensured and that the soil reaction throughout that layer is brought at a pH of 6.0-6.5.

(*c*) Spreading the phosphate dressing through the top 12 inches of soil around the plant has proved to be the most effective method. In an attempt to maintain the phosphate status of that soil layer at a desired level for the duration of the planting cycle, it does not seem advisable to give all the phosphate at once, as too high a phosphate concentration in the soil might have an inhibiting influence on the yield of the first crop.

(*d*) On acid soils mono-calcium phosphate is more effective than either di- or tri-calcium phosphate under both unlimed and limed conditions. Therefore, it is advisable to use water soluble phosphates. The granulated form is the best, as granules will spread easily when applied creating numerous specks of high phosphate concentration through the soil. When only small phosphate dosages are needed, superphosphate 20 percent will offer an advantage over superphosphate 40 percent containing double the amount of granules.

(*e*) Under certain conditions it may be good and economic to apply the phosphate as a solution. When applied (*e.g.*, in ratoons) to a slightly moist soil, the solution will permeate through the soil to a considerable depth and width. The solution can also be enriched with nitrogen if high graded ammonium phosphates are used as the basic material.

REFERENCE

"The use of pot tests in research on the fertility of sugarcane soils" *Trop. Agriculture Trin.* Vol. 30. (Nos. 10-11) Vol. 31. (Nos. 1-4).

Dr. D. K. Patel presented the following two papers.

Paper

SOME ASPECTS OF PHOSPHATE MANURING TO SUGARCANE IN DECCAN CANAL SOILS

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Phosphorus is one of the three major plant nutrients. In importance, it is next to nitrogen in Indian Agriculture. Its need is being recognised in manuring practices along with nitrogen, in recent years, under intensive cultivation aiming high production.

However, it considerably differs from nitrogenous fertilizers in its behaviour in soil. Nitrogenous fertilizers when applied to soil remain available to crop, move freely in soil profile through soil moisture and possess the only danger of being leached out or lost, if applied in excess. Phosphatic fertilizer like superphosphate, when applied to soil, remains wherever it is placed. Its lateral or downward movement is practically very little and so it possesses no danger of being leached out or lost. But it has the characteristic property, a great disadvantage, of getting fixed or reverted from soluble to insoluble form in contact with soil thus rendering itself unavailable to crop.

Now it is an accepted fact that soluble phosphatic fertilizers like superphosphate, when applied to soil get reverted or fixed to a considerable extent. Hopkins (8) came to the conclusion that the standard of our major phosphatic fertilisers added to soil, reverts to less available form by soil fixation. Lewis, Baker and Snyder (10) observed that in calcareous soils of western U.S.A., numerous chemical reactions and physical changes take place that render soluble phosphatic fertilizers unavailable for plant use, McGeorge and co-workers (7) have found strong fixing power for soluble phosphates in calcareous soils because of free calcium carbonate and gave evidence of the formation of tri-calcium phosphate. Patel and Vishwanath (11) in their comparative studies of Indian soils about phosphate fixing capacity have reported that clayey soils (black cotton soils) have high fixing capacity and that free lime in soil (calcareous soils) tremendously increases the fixing capacity. Raghavan and Patel (13) in their studies of Deccan Canal soils have made similar observations.

The soils of Deccan Canal area are highly clayey and calcareous with free lime status varying from 3 to 15 percent. In view of this, insoluble fertilizers like rock phosphate, basic slag and bone-meal are not suitable in Deccan Canal area. The use of soluble phosphatic fertilizers like superphosphate is only advisable but its use presents a problem in highly clayey calcareous soils.

This paper presents a series of laboratory investigations and field experimentations carried out at Sugarcane Research Station, Padegaon, to devise ways and means of its full exploitation.

INVESTIGATIONS ON THE PHOSPHATE AVAILABILITY IN MAJOR SOIL TYPES

These studies were carried out in small pots applying P_2O_5 at the rate of 500 pounds per acre to A, B, D, F and G soil types. The superphosphate and soil were thoroughly mixed and the pots were maintained at the respective moisture-equivalent level. A representative soil sample was collected from each pot at the interval of ten days over a period of hundred days. A control for each soil type was maintained under identical conditions.

The available P_2O_5 was determined by Truog's method (14) and the results are given in Table I.

The data show that the phosphate availability decreases steadily with time in all soil types, the decrease being faster at beginning. Moreover, the availability decreases faster in soils having higher $CaCO_3$ content due to greater fixation. It is interesting to note that phosphate availability increases slightly after 50-60 days, probably due to availability of organic phosphate on decomposition. This is supported by a similar trend with the controls. The results of the availability of superphosphate with respect to time gives a gloomy picture as only 5 to 10 percent of the applied phosphate remains available after about 3 months. It was therefore felt necessary to investigate the relative fixing power of the different soil types to find out the saturation limit.

INVESTIGATION ON PHOSPHATE FIXATION IN THE MAJOR SOIL TYPES

Laboratory experiments were conducted with 3 levels of 250, 500 and 1,000 lbs. P_2O_5 per acre as superphosphate on A, B, D, F and G soil types. One hundred grams of soil was treated with superphosphate on the basis of the above quantities in 500 ccs. of water with occasional shaking and filtered after 24 hours. The phosphate retained after washing the soil with five instalments of 100 ccs. of

TABLE I

PHOSPHATE AVAILABILITY AT 10 DAYS' INTERVAL IN MAJOR SOIL TYPES OF DECCAN CANAL TRACT (TRUOG'S METHOD)

Soil	Treatment	Available P_2O_5 mgms./100 gms soil after every 10 days										
		Initial	10 days	20 days	30 days	40 days	50 days	60 days	70 days	80 days	90 days	100 days
A	Control	6.32	6.23	6.03	6.56	7.82	7.64	7.21	6.25	5.75	2.67	3.56
	Treated	13.78	9.49	9.62	10.00	10.75	10.42	10.36	8.25	7.94	6.33	6.25
	*	29.84	13.04	14.36	13.76	11.72	11.12	12.60	8.00	8.76	14.64	10.76
B	Control	6.34	7.46	6.18	5.63	3.62	4.25	4.82	4.28	4.16	3.81	3.26
	Treated	14.72	10.46	9.36	8.78	5.70	6.09	6.12	5.90	5.00	4.29	3.88
	*	33.52	12.00	12.72	12.60	8.32	7.36	5.20	6.48	3.36	1.92	2.40
D	Control	4.42	4.34	4.41	4.49	4.11	4.70	4.50	4.00	3.62	3.14	2.08
	Treated	9.62	5.45	5.36	6.31	7.88	7.58	7.70	6.61	5.25	5.00	4.45
	*	20.76	14.04	19.00	15.08	17.28	14.52	12.00	10.44	6.52	7.44	9.45
F	Control	5.75	4.30	4.00	4.00	4.71	4.40	4.70	4.23	4.20	4.00	3.95
	Treated	13.75	9.36	9.30	8.32	8.20	8.50	8.28	7.16	6.50	6.21	5.96
	*	32.00	20.24	21.20	17.28	14.00	16.36	14.32	11.72	9.20	8.84	8.04
G	Control	7.32	6.50	6.20	6.48	7.79	8.00	7.95	6.50	5.00	3.82	3.74
	Treated	9.00	8.32	8.25	7.91	8.50	10.55	9.30	8.82	7.50	6.75	6.75
	*	6.72	7.24	5.72	2.04	10.20	5.40	9.28	10.00	11.72	12.04	12.62

* The figures indicate the percentage of P_2O_5 available out of the added P_2O_5.

water, represented the amount of P_2O_5 actually fixed. Simultaneously calcium carbonate was determined in these soils. The data are given in Table II.

TABLE II

PHOSPHATE FIXATION IN MAJOR SOIL TYPES AT VARIOUS LEVELS OF APPLICATION

Soil types	Free $CaCO_3$ %	Percentage phosphate fixation at various levels		
		250 lbs. per acre	500 lbs. per acre	1000 lbs. per acre
A	5.01	93.52	87.80	69.30
B	10.14	93.80	88.56	77.56
D	8.76	95.81	90.12	79.72
F	3.05	85.44	82.36	56.72
G	6.92	87.60	79.50	69.46

In Table II, the results of phosphate fixation are given for A, B, D, F and G soil types when phosphate is applied at the rate of 250 pounds, 500 pounds and 1,000 pounds per acre. The percentage fixation shows that all soil types have high capacity to fix phosphate. With a dose of 250 lbs. of P_2O_5 per acre, 85 to 95 percent is fixed. Even with increasing doses of 500 and 1,000 pounds P_2O_5 per acre, the fixing capacity of these soils is far away from saturation limit. The results also show that percentage fixation is related to $CaCO_3$ content. There is a good correlation between fixation and $CaCO_3$ content at the level of 1,000 pounds P_2O_5 per acre. The correlation is not so striking at 250 pounds and 500 pounds per acre levels as $CaCO_3$ has got tremendous fixing capacity and these levels fall far below the saturation capacity of individual soil. Patel and Vishwanath (11) have reported similarly about Black Cotton soils of India, in general.

Data of available phosphate without destroying $CaCO_3$ and after destroying $CaCO_3$ of the soil, in the treated and washed soil samples are given in Table III.

TABLE III

AVAILABILITY OF P_2O_5 AT VARIOUS LEVELS OF PHOSPHATE APPLICATION BEFORE AND AFTER DESTROYING $CaCO_3$ (TRUOG'S METHOD)

Soil type	$CaCO_3$ %	Available P_2O_5 in mgms. per 10 gms. of soil after phosphate fixation					
		With 250 lbs. per acre		With 500 lbs. per acre		With 1000 lbs. per acre	
		a	b	a	b	a	b
A	5.01	17.44	35.92	17.86	42.37	42.00	66.67
B	10.14	7.62	24.14	18.56	35.80	17.75	57.69
D	8.76	4.68	42.23	7.58	47.17	11.66	53.57
F	3.05	20.59	36.01	25.00	38.11	35.88	50.00
G	6.92	20.49	46.80	22.49	48.86	34.26	51.65

(a) Before destroying $CaCO_3$; (b) After destroying $CaCO_3$.

The above data clearly indicate that the availability of phosphorus increases tremendously after destroying calcium carbonate in all soil types. Basu and Kibe (6) have observed the same thing in their study of 'B' soil type. The tremendous increase in phosphate availability in all soil types on destroying $CaCO_3$ clearly shows that most of the applied phosphate is fixed as calcium compound in calcareous soils.

An interesting conclusion of the results in Table II, that percentage fixation decreases as the dose of phosphate application increases, has great practical value. Application by broadcast of 100 to 150 pounds of P_2O_5 per acre will be more or less completely fixed due to dilution and the availability may be about 5 to 10 percent at the most. If strips 6″ wide are marked out at a distance of 4 feet over a field that has received 1,000 lbs. P_2O_5 per acre by broadcast, it can be taken that these strips have received about 100 pounds P_2O_5 and the available P_2O_5 in these strips is about 30 to 40 percent, according to findings of Table II. As soluble phosphatic fertilizers hardly move a few inches in soil, an application of 100 pounds of P_2O_5 in rows or bands will keep about 30 to 40 percent phosphate in available form, a theoretical finding of great importance in practice. This is the underlying principle of phosphate application in rows or bands to have the least mixing with the soil thereby maintaining much higher availability compared to broadcast application.

Application of phosphate in a band or row, maintains better availability yet the finding has to be practically utilised in relation to crop i.e. the band or row placement of superphosphate should be wherever there is maximum accumulation of roots and where there is sufficient moisture available to the roots to expand. A series of agronomic experiments on the placement of phosphate with reference to sugarcane have been carried out at the Suagrcane Research Station, Padegaon.

AGRONOMIC EXPERIMENTS ON PLACEMENT OF PHOSPHATE AND PERIODICAL FERTILITY STUDIES

A series of agronomic experiments (2, 3, 4 and 5) on placement of phosphate were carried out at this Research Station during the years 1950 to 1955. The placements studied were 0, 3 and 6 inches deep in the furrow for deep soils and surface, half way down and bottom of the ridge for shallow soils. These agronomic experiments have clearly borne out that the placements of 6 inches deep in furrow for deep soils and half way down the ridge for shallow soils are superior to other placements as regards effective tillering and yields. The data on periodical fertility studies carried out in these placements of phosphate experiments are given in Table IV.

TABLE IV

PERIODICAL AVAILABILITY OF PHOSPHATE WITH DIFFERENT PLACEMENTS IN MGMS. PER 100 GMS. OF SOILS

(*a*) *Deep soils*

Treatment 1	Sept. 1952 2	Jan. 1953 3	March 1953 4	May 1953 5	July 1953 6	Sept. 1953 7	Nov. 1953 8
0″ Placement	19.1	14.5	18.5	19.9	21.8	18.9	23.1
3″ Placement	15.4	10.5	18.0	23.2	22.3	16.4	20.9
6″ Placement	16.5	11.4	26.1	18.7	25.4	16.5	24.1
P_2O_5 in two doses, half at planting and half at earthing up	11.6	9.5	23.2	23.6	29.1	11.2	27.9

(*b*) *Light soils*

Treatment	December 1952	February 1953	April 1953	June 1953	August 1953	October 1953
In furrows	7.4	6.5	10.0	9.3	10.8	9.9
Half-way down the ridge	9.3	5.0	11.3	9.1	24.1	8.8
At the bottom of the ridge	7.0	4.0	7.4	6.7	15.0	7.3

The above results (3 and 4) show that placement of phosphate 6 inches deep in furrow maintained highest availability in deep soils while the placement half-way down the ridge, has maintained the highest availability in shallow soils. These findings fully support the conclusions of agronomic experiments.

Moreover, the periodical fertility studies (9) carried out in all important agronomic experiments during 1952-53 and 1953-54 have given an indication that phosphate availability should remain fairly good at the beginning but should increase towards the end of growth cycle of sugarcane for purity and high recovery. This pointed out that half the dose of phosphate be given at planting and half at the time of earthing up by placement. Periodical fertility studies given in table IV (a) under two doses of P_2O_5 have shown that this method of application can serve the purpose. Indications of obtaining higher sugar when P_2O_5 is applied in two doses (at planting and earthing up time) are observed in agronomic experiments.

PHOSPHATE CARRIER EXPERIMENTS—FIELD STUDIES

Application of phosphate by placement is only a partial solution of the problem, as it maintained only 30 to 40 percent of applied superphosphate in available form, while 60 to 70 percent of it was still getting reverted or fixed in soil. As the fixation is mainly due to mixing with soil (soil contact), it was thought worthwhile to apply superphosphate mixed with organic materials to maintain better availability of phosphate by protecting it from getting fixed in soil. A series of experiments were carried out applying superphosphate through carriers.

An experiment was carried out in chopan (reclaimed) soil during 1952-53 (3) applying P_2O_5 at the rate of 500 pounds per acre as superphosphate. High dose was used due to chopan (sodiumised) area. Superphosphate was mixed with bagasse or compost in the proportion of 1 : 5, like cement and mortar adding enough moisture for a period of one week with one turning.

The loose mixture was used for application by placement in the furrow. A control treatment was included wherein the carrier and superphosphate were applied separately.

The carrier treatments gave a superior performance over the control but the experiment was repeated as there was a heavy attack of borer with control treatment. The results of the same experiment (4) carried out in adjoining chopan (reclaimed) plot are given in Table V.

TABLE V

ROLE OF COMPOST AND BAGASSE AS PHOSPHATIC CARRIERS ON THE GROWTH OF SUGARCANE 1953-54

Sl. No.	Treatment	Brix	Plant population per acre	Yield tons per acre
1	Control	21.2	32262	41.2
2	Compost+P_2O_5	21.5	34885	51.7
3	Control	19.7	29639	35.5
4	Bagasse +P_2O_5	20.5	34154	42.8

The data given above clearly show that by the application of phosphate through carriers i.e. thorough mixing of superphosphate with bagasse or compost with occasional stirring even for a short period of about a week, proves highly beneficial for better quality of cane and yields. Compost seems to be superior to bagasse as a phosphate carrier for response in yields. The experiments were continued during the year 1954-55 also, including dung as a phosphate carrier in the adjoining plot, and the ratoon of the previous experiment was continued in the same plot with fresh phosphate application through carriers. The results of these experiments were also promising but were not so striking as those of Table V because the continued experimentation in the same plots made the inherent availability of phosphate in soil quite high. Recently, Acharya (1) has recommended application of superphosphate mixed with well-fermented compost (25 to 50 times) and observed that the fixation of superphosphate in insoluble form in the soil could be minimised to a considerable extent. Walunjkar and Acharya (15), very recently, observed that the mixture of superphosphate and compost or superphosphate added to compost pit gave higher crop yields than superphosphate applied separately along with compost.

As the field experiments of applying superphosphate through carriers gave very promising results, it was felt necessary to evaluate how much superphosphate was maintained in available form by mixing with organic materials, due to protection.

PHOSPHATE CARRIER EXPERIMENT—LABORATORY STUDIES

Detailed laboratory studies were undertaken with a view to evaluate the efficiency of three different carriers, used in field experiments, viz., compost, bagasse and dung. The experiment was carried out in pots of one foot diameter. A weighed quantity of the above mentioned carriers was taken in separate pots in duplicate with one control in each case. Single superphosphate (18% soluble P_2O_5) was mixed thoroughly with the carrier in pots (1 part superphosphate + 5 parts carrier) and the whole mixture was kept in moist condition. Periodical samples were taken after 1, 3, 4, 8, and 16 weeks. Moisture was made up in the pots the previous day before taking the samples after thorough mixing. The samples were dried in sun and analysed as such. Four different forms of phosphate were estimated from each sample in duplicates. The details of the procedure are as under.

(1) *Water soluble (diffused) phosphate* : A weighed amount (5 gms.) of the air-dried sample was allowed to be soaked in distilled water for one hour without stirring the contents, the ratio of sample and water being 1 : 100. A suitable quantity of the supernatent liquid from the treated and the control, was taken for determining the phosphate content by the normal volumetric method destroying the organic matter by the use of nitric acid. *This form of phosphate was considered liable to be fixed in soil.*

(2) *Adsorbed or absorbed phosphate* : Residue remaining after water extract, as above, was macerated with NH_4Cl and filtered off, repeating this process 5 times. The phosphate thus extracted was estimated. *This form of phosphate was considered as available due to protection.* Due consideration was given to water insoluble but HCl soluble phosphate content of superphosphate. This was further confirmed by running a separate experiment with mixture of dung and water extracted phosphate from superphosphate.

(3) *Organic phosphate* : The residue after maceration was used for phosphate estimation following usual precautions. This form of phosphate is also taken as available due to decomposition of organic matter in due course.

(4) *Total phosphate* : This was determined by the normal procedure using 5 gms. of sample and taking all precautions of the loss of phosphate by volatilization during the course of ignition (12).

The results of the analysis are presented in Table VI.

TABLE VI

PHOSPHATE CARRIER EXPERIMENT—LABORATORY STUDIES OF THE DIFFERENT FORMS OF PHOSPHATE ALONG WITH AVAILABLE (PROTECTED) PHOSPHATE ON APPLYING SUPERPHOSPHATE THROUGH DIFFERENT CARRIERS

		Percentage P_2O_5 on oven dry basis Carriers					
		Bagasse		Compost		Dung	
Period of sampling	Different forms of phosphate	Bagasse + Superphos	Bagasse only	Compost + Superphos	Compost only	Dung + Superphos	Dung only
One week	Water soluble	3.10	0.06	0.71	0.04	2.08	0.23
	Adsorbed/Absorbed Protected	1.38	0.07	4.22	0.67	6.09	0.53
	Organic	0.10	0.05	0.20	0.14	0.23	0.10
	Total	4.76	0.17	5.23	0.92	9.05	0.86
	Available Phosphate (Protected) % fraction of total	28.14	—	84.24	—	75.53	—
Three weeks	Water soluble	3.27	0.16	0.62	0.10	1.78	0.10
	Adsorbed/Absorbed Protected	1.87	0.07	4.16	0.68	7.56	0.55
	Organic	0.34	0.08	0.72	0.24	0.54	0.27
	Total	5.24	0.24	5.27	0.82	9.88	1.08
	Available Phosphate (Protected) % fraction of total	39.81	—	88.28	—	82.80	—
Four weeks	Water soluble	3.23	0.03	0.15	0.02	0.84	0.06
	Adsorbed/Absorbed Protected	1.76	0.03	4.94	0.74	7.90	0.53
	Organic	0.45	0.09	0.44	0.04	0.55	0.25
	Total	5.21	0.15	5.36	0.88	9.59	1.06
	Available Phosphate (Protected) % fraction of total.	39.47	—	97.23	—	91.23	—
Eight weeks	Water soluble	3.28	0.003	0.12	0.01	0.65	0.06
	Adsorbed/Absorbed Protected	1.96	0.07	5.06	0.74	8.46	0.83
	Organic	0.36	0.12	0.35	0.18	0.58	0.38
	Total	5.75	0.15	5.76	0.99	9.86	1.29
	Available Phosphate (Protected) % fraction of total	39.53	—	97.73	—	91.41	—
Sixteen weeks	Water soluble	3.19	0.002	0.13	0.004	0.38	0.06
	Adsorbed/Absorbed Protected	2.21	0.05	4.85	0.76	8.83	0.83
	Organic	0.29	0.12	0.38	0.16	0.54	0.27
	Total	6.73	0.17	5.37	0.96	10.34	1.37
	Available Phosphate (Protected) % fraction of total	42.15	—	97.21	—	96.26	—

In Table VI the phosphate which is adsorbed/absorbed and converted into organic form is taken as available phosphate due to protection by the carriers. Over and above, about 30 to 40 percent of the water soluble (diffused) phosphate should also be considered as available under placement method.

The data show it clearly that about 70 to 80 percent of superphosphate can be maintained in available form by applying through carriers like compost or dung, even with a short mixing period of about a week. The availability of phosphate due to protection goes on increasing as the period of keeping them mixed goes on increasing ; and thus availability rises upto 95 percent within four months. It will also be obsereved that the water soluble phosphate which is liable to be fixed is the highest at the beginning and goes on decreasing with time.

The application of superphosphate through compost or dung as carriers, seems to be more beneficial as compared to bagasse. Comparison between compost and dung shows that compost has maintained higher availability of P_2O_5 than dung, but dung is superior to compost as a carrier if one takes into consideration the percentage concentration of phosphate in both the carriers. The application of phosphate through carriers has a further advantage that it maintains availability steadily over a longer period due to slow decomposition of the organic matter (carrier).

CONCLUSIONS

1. The availability of applied phosphate (superphosphate) steadily decreases with time in all soil types,the decrease being faster at beginning due to fixation.

2. Deccan Canal soils being highly calcareous have high phosphate fixing capacity, which is correlated to the free lime content. Even with a dose of 1,000 pounds of P_2O_5 per acre as superphosphate applied by broadcast, only about 30 to 40 percent remains in available form.

3. Application of phosphate in a band or row (100 lbs.) will maintain about 30 to 40 percent in available form due to localised concentration and their decreased fixation.

4. Phosphate should be applied by placement in zone where there is maximum concentration of roots and enough moisture always available for roots to expand. Several agronomic experiments on placement of phosphate have clearly shown that the placements of 6 inches deep in the furrow for deep soils and half way down the ridge in shallow soils, are advisable for effective tillering and increase in cane yields. Periodical fertility studies showed that these placements maintain the highest availability of phosphate compared to other placements.

5. The periodical fertility studies have further indicated that higher availability of phosphate should be maintained towards the end of the growth cycle for better maturity. Application of phosphate in two doses half at planting and half at earthing up served the purpose as indicated by the periodical fertility studies. Agronomic experiments showed that higher sugar is obtained by this way.

6. Application of phosphate (superphosphate) through carriers like compost

or dung helps to maintain the availability to a greater extent due to protection. Laboratory studies have shown that even mixing like cement-mortar, for a short period of about a week, helps to maintain 70 to 80 percent of the phosphate in available form. By increasing the period of mixing up to 4 months, the availability due to protection can be increased up to 95 percent. Compost or dung as carriers are found satisfactory for practical purposes. Field studies have given very promising results in applying superphosphates through carriers.

7. Application of phosphate through carriers is only a practical solution to avoid fixation which minimised the use of granular or pellet form superphosphate in Western countries. However, the application of phosphate through carriers has a further advantage that the availability is maintained steadily over a longer period due to slow decomposition of engulfing organic matter (carrier). This has an additional advantage for a long growing crop like sugarcane.

8. The detailed investigations embodied in this paper suggest that investigations should be carried out about the comparative availability of organic phosphates (fertilizers) in Deccan Canal soils.

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Paper

SOIL CHANGES UNDER DIFFERENT CULTURAL AND MANURIAL PRACTICES IN DECCAN CANAL AREA

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INTRODUCTION

In Deccan Canal tract, calcareous,highly clayey (Montmorillonitic), deep soils of moderate drainage and black in colour predominate. Sugarcane is the major crop grown year after year in this area under intensive methods of cultivation. With a view to study the effects of various factors of cane growing viz., water, manure, fallowing, rotational cropping, etc., on soil properties, and finally to evolve sound agricultural practices, a series of long range experiments under controlled conditions were started at the Sugarane Research Station, Padegaon. Some of the results obtained are briefly discussed below.

SOIL CHANGES UNDER CONTINUOUS IRRIGATION AND DIFFERENT MANURIAL PRACTICES

This (1) is an irrigational (10 days interval) uncropped series, started since 1932, receiving normal cultural operations with periodical weeding. The experiment consists of three irrigational treatments without any manurial dose and eleven manurial treatments under one irrigational dose of 95 acre-inches only. The manurial treatments include bulky manures, nitrogenous manures (both organic and inorganic), phosphatic and potassic fertilizers. A control treatment, without irrigation and manure, receiving only cultural operations, has also been included. The experiment has been laid out in simple randomised block design in duplicates, with plots measuring 0.5 cent.

Soil samples upto 2 feet depth (at an interval of 6″) were collected in 1952 and analysed in detail for different fertility constituents viz., pH, free lime, exchangeable calcium, humus, organic carbon, total nitrogen, available phosphate and available potash by standard methods (9).

(*i*) *Soil changes under continuous irrigation.* Three irrigational doses of 70A″, 95A″ and 120A″ inclusive of 10″ of effective rainfall, did not produce remarkable or specific changes in the different fertility constituents. Continuous irrigation has, however, been slightly effective in reducing the pH with increasing doses.

(*ii*) *Soil changes under organic manures and nitrogenous fertilizers.* The various organic manures and nitrogenous fertilizers applied to soil every year were farm yard manure, sann hemp (green manure) safflower cake, sulphate of ammonia, calcium cynamide and nitrate of soda, the dose of application being 300 lbs. N per acre. The results are given in Table I.

TABLE I

SOIL CHANGES UNDER ORGANIC MANURES AND NITROGENOUS FERTILIZERS

Particulars	Depth	Control	F.Y.M.	Sann hemp	Safflower cake	Sulphate of ammonia	Calcium cynamide	Sodium nitrate
pH	0-6″	8.4	8.2	8.2	8.2	7.6	8.6	8.6
	6-12″	8.4	8.2	8.4	8.2	7.8	8.4	8.6
	12-18″	8.3	8.0	8.2	8.2	8.1	8.3	8.5
	18-24″	8.5	8.2	8.5	8.1	8.1	8.3	8.3
Humus %	0-6″	1.05	1.14	1.11	0.94	0.76	0.86	0.84
	6-12″	1.15	1.04	1.09	0.88	0.70	0.77	0.80
	12-18″	0.89	0.96	0.91	0.81	0.69	0.82	0.80
	18-24″	0.74	0.87	0.81	0.75	0.65	0.65	0.70
Organic carbon %	0-6″	0.90	0.94	0.90	0.86	0.69	0.74	0.73
	6-12″	0.82	0.91	0.88	0.58	0.65	0.70	0.70
	12-18″	0.78	0.89	0.75	0.53	0.60	0.67	0.66
	18-24″	0.78	0.84	0.60	0.52	0.53	0.65	0.60
Total nitrogen %	0-6″	0.045	0.055	0.061	0.066	0.090	0.066	0.076
	6-12″	0.043	0.041	0.058	0.073	0.084	0.058	0.071
	12-18″	0.041	0.042	0.047	0.066	0.084	0.058	0.071
	18-24″	0.043	0.047	0.050	0.050	0.083	0.057	0.076
Available P_2O_5 mgs 100 gms soil	0-6″	5.56	21.12	18.56	13.16	10.30	6.51	8.14
	6-12″	4.66	17.14	15.81	15.52	9.22	5.50	7.12
	12-18″	4.50	11.72	17.44	17.24	8.17	4.93	7.38
	18-24″	4.84	6.25	13.73	19.23	8.57	5.19	6.15
Available K_2O mgs 100 gms soil	0-6″	48.10	66.30	50.00	34.70	50.00	58.90	40.60
	6-12″	39.30	77.40	50.00	40.10	53.60	53.60	33.80
	12-18″	31.80	69.40	40.90	30.00	53.40	62.50	45.00
	18-24″	42.40	48.20	38.10	31.90	45.40	53.60	31.90

Amongst all the nitrogenous treatments, sulphate of ammonia has come out the best showing 143 percent increase in the first half foot of the soil, the average increase being 96 percent up to a depth of two feet. The data further show that the application of the three chemical fertilizers have resulted in relatively better nitrogen status of soil than the bulky manures and the safflower cake. Farm yard manure has shown the highest loss in nitrogen status of soil. Farm yard manure and sann have,however, increased significantly, the humus and organic carbon status of soil whereas sulphate of ammonia has brought about the maximum loss of organic carbon and humus throughout the four depths studied but it has appreciably reduced the pH of the soil throughout the four depths. Farmyard manure has increased the availability of phosphorus as well as of potash.

(*iii*) *Soil changes under phosphatic fertilizers.* The different phosphatic fertilizers applied were superphosphate, bonemeal and basic slag. Six hundred pounds of phosphate (P_2O_5) per acre were applied every year during the last 22 years. The results showing the total nitrogen and available phosphate percentages are given in Table II.

TABLE II

SOIL CHANGES UNDER PHOSPHATIC FERTILISERS

Treatment	Depth	Total nitrogen percent	Available P_2O_5 mgms. 100 gms. soil
Control	0-6″	0.045	5.56
	6″-12″	0.043	4.66
	12″-18″	0.041	4.50
	18″-24″	0.043	4.84
Basic slag	0-6″	0.050	20.00
	6″-12″	0.042	15.54
	12″-18″	0.048	16.66
	18″-24″	0.042	7.62
Super phosphate	0-6″	0.053	28.71
	6″-12″	0.049	21.27
	12″-18″	0.045	13.30
	18″-24″	0.046	Trace
Bonemeal	0-6″	—	25.12
	6″-12″	—	12.50
	12″-18″	—	6.46
	18″-24″	—	5.42

The results show that the movement of added P_2O_5 is much less than that of nitrogen as the first two depths have shown the highest phosphate content. As expected, the available phosphate is the highest in the phosphatic treatments (compare Table I), the best in this respect being the superphosphate. From a joint study of the data in Tables I and II,it could be seen that the bulky manures as well as safflower cake have shown higher availability of phosphate as compared to chemical fertilizers, farm yard manure being the best in this respect. It is very interesting to note that the nitrogen level of soil, receiving phosphatic fertilisers, has increased compared to control plots. This indicates that the phosphatic fertilizers have helped in building up the nitrogen status of the soil. Moreover, periodical soil microbiological studies have also shown that the non-symbiotic nitrogen—fixing organisms are more in number in plots receiving phosphatic fertilizers.

(*iv*) *Soil changes under potassic fertilisers.* Six hundred pounds of potash (K_2O) per acre per year were applied in the form of sulphate of potash and muriate of potash. The K_2O status of the soils under these two potassic fertilizers as well as under the farm yard manure is given in Table III.

TABLE III

SOIL CHANGES UNDER POTASSIC FERTILISERS

Depth	Particulars	Control	Sulphate of potash	Muriate of potash	Farm yard manure
0-6″	Available	48.10	77.90	80.03	66.30
6-12″	K_2O in	39.30	42.90	46.20	77.40
12-18″	mgms/100	31.80	55.30	41.80	69.40
18-24″	gms of soil	42.40	37.50	35.10	48.20

Sulphate of potash as well as the muriate of potash are practically alike as potassic fertilisers and have shown the maximum availability of potash among the manurial treatments, the next in order being the farm yard manure. The latter treatment has improved the K_2O status of all depths of the soil.

SOIL CHANGES UNDER DIFFERENT SYSTEMS OF CONTINUOUS CROPPING AND FALLOWING

This experiment (2) was started in 1932 and was continued since. It is laid out in simple randomised block design with plots measuring 2.5 cents each. The experiment includes five types of fallows :—(1) dry, (2) cultivated and irrigated, (3) uncultivated and irrigated, (4) cultivated and unirrigated, and (5) cultivated, irrigated and manured and three types of cane plantings—plant, ratoon and Adsali. It also includes a rotational type of sugarcane cropping called Manjari standard method where the sann-cane-sorghum rotation is followed. The manurial doses for the different treatments are as under :—

1. Cultivated, irrigated and manured	40 cartloads of F. Y. M.—150 lbs. nitrogen per acre in the form of sulphate of ammonia : cake 1:1 ratio.
2. Plant cane manured	40 cartloads of F. Y. M.—150 lbs. nitrogen per acre in the form of sulphate of ammonia : cake 1:1 ratio.
3. Adsali cane manured	40 cartloads of F. Y. M.—200 lbs. nitrogen per acre in the form of sulphate of ammonia : cake 1:1 ratio.
4. Manjari standard method (sann-cane-sorghum rotation)	150 lbs. nitrogen per acre in the form of sulphate of ammonia : cake 1:1 ratio.
5. Ratoon manured	100 lbs. nitrogen per acre in the form of sulphate of ammonia : cake 1:1 ratio.

1. *Fertility studies* :—

Soil samples upto 2 feet depth, at an interval of 6″, were collected in 1952 after harvest and were analysed for total nitrogen, available P_2O_5 and K_2O by standard methods (9).

The analytical data for one of the three blocks (Medium series) are represented in Tables IV(a) and IV(b).

TABLE IV(a)

SOIL CHANGES UNDER DIFFERENT SYSTEMS OF CROPPING AND FALLOWING

		Fallows				
Particulars	Depth	Dry	Cultivated and irrigated	Uncultivated and irrigated	Cultivated and unirrigated	Cultivated, irrigated and manured
Humus%	0-6″	0.81	0.72	0.76	0.68	0.82
	6-12″	0.72	0.62	0.71	0.63	0.83
	12-18″	0.43	0.65	0.71	0.54	0.74
	18-24″	0.37	0.62	0.66	0.48	0.63
Total nitrogen%	0-6″	0.049	0.046	0.048	0.047	0.076
	6-12″	0.046	0.045	0.041	0.045	0.070
	12-18″	0.046	0.046	0.039	0.042	0.062
	18-24″	0.042	0.043	0.034	0.032	0.048
Available P_2O_5 mgms/ 100 gms.	0-6″	3.90	5.70	4.60	3.10	15.30
	6-12″	3.80	4.90	3.80	2.80	11.90
	12-18″	3.80	4.50	3.70	2.50	8.80
	18-24″	3.10	3.70	3.30	Trace	5.20
Available K_2O mgms/ 100 gms. soil	0-6″	27.40	18.80	28.50	23.20	75.00
	6-12″	28.90	14.10	25.00	18.90	64.20
	12-18″	18.00	13.80	24.40	18.60	64.50
	18-24″	Trace	15.50	14.70	13.40	60.20

TABLE IV (b)

		Plant cane		Ratoon		Adsali		
Particulars	Depth	Unmanured	Manured	Unmanured	Manured	Unmanured	Manured	Manjari standard method
Humus %	0-6″	0.51	0.61	0.50	0.45	0.64	0.63	0.56
	6-12″	0.49	0.63	0.48	0.45	0.69	0.59	0.54
	12-18″	0.34	0.55	0.37	0.34	0.31	0.54	0.33
	18-24″	0.30	0.45	0.29	0.31	0.30	0.44	0.34
Total nitrogen %	0-6″	0.046	0.074	0.058	0.063	0.052	0.070	0.056
	6-12″	0.044	0.057	0.053	0.046	0.045	0.049	0.034
	12-18″	0.037	0.043	0.043	0.043	0.039	0.041	0.032
	18-24″	0.026	0.036	0.035	0.040	0.039	0.035	0.028
Available P_2O_5 mgms/ 100 gms. soil	0-6″	4.70	8.20	3.10	7.30	3.50	6.70	6.20
	6-12″	4.60	5.60	2.70	6.10	2.90	5.60	5.00
	12-18″	4.30	4.90	Trace	5.80	Trace	5.00	3.40
	18-24″	2.90	Trace	Trace	5.00	Trace	4.30	3.10
Available K_2O mgms/ 100 gms.soil	0-6″	23.90	52.70	29.50	50.40	20.50	51.50	42.00
	6-12″	18.30	48.70	26.30	49.60	25.30	48.70	42.70
	12-18″	17.00	41.40	25.70	40.50	16.50	41.70	35.90
	18-24″	13.20	38.40	29.10	35.60	12.30	40.90	32.60

The fallow plots clearly show that cultivations and/or irrigations deplete humus and deterioration in physical condition of the soil is brought about by intensive cultivation under irrigation. Manuring of the fallow plot has helped to maintain the humus content as well as enhancing nutrient status of soils.

Continuous cropping without manuring for all the three types of planting show that there is a general depletion of plant nutrients including humus. Manuring of the plots under four types of plantings has increased total N, available P_2O_5 and K_2O but there is an indication of the humus status of the soil.

LYSIMETER SERIES—SOIL CHANGES UNDER COMPOST AND GREEN MANURING IN DIFFERENT SOIL TYPES

This series has been laid out since 1938. The investigation is in progress in two sets of lysimeters on six important soil types, one set being under cotton-cane rotation and the other under sann-cane. The objective of the experiment is to study the relative value of compost and green manuring in maintaining the fertility of soil in different soil types. These sets of lysimeters are grown under cane in alternate years. Each set consists of two lysimeters of each soil type, one of which has been receiving 100 lbs. P_2O_5 since the last six cycles of cane crop. Each lysimeter measured 1/1000 of an acre and received 300 lbs. nitrogen per acre for every cane crop. A basal dose of 20 cartloads of compost was also given to cane crop in cotton-cane series while sann was grown and dumped in the sann-cane series.

One foot soil samples were collected from the cotton-cane series and the sann-cane series during the years 1952 and 1953 and they were analysed for different fertility constituents by standard methods (9). The results of analysis of no-phosphate treatments from cotton-cane series and sann-cane series are given below in Table V.

TABLE V

SOIL CHANGES UNDER COMPOST AND GREEN MANURING IN DIFFERENT SOIL TYPES

Depth	Soil type	Humus%		Organic carbon %		Total N %		Av.P_2O_5 mgms/100 gms soil	
		1	2	1	2	1	2	1	2
1951-52									
0—12″	A	0.582	0.591	2.12	1.39	0.111	0.085	3·8	3.0
,,	B	0.687	0.525	1.61	1.43	0.087	0.050	5.2	2.3
,,	C	0.706	1.287	1.85	1.29	0.069	0.062	4.9	2.3
,,	D	1.364	1.097	1.85	1.13	0.116	0.094	3.5	Trace
,,	F	0.868	1.011	1.74	0.91	0.104	0.080	9.6	2.3
,,	G	0.487	0.353	1.69	1.40	0.116	0.092	8.9	3.3
1954-55									
0—12″	A	1.221	1.326	1.44	1.28	0.088	0.071	4.7	2.8
,,	B	0.830	1.135	1·65	1.22	0.103	0.088	3.8	2.7
,,	C	0.735	0.572	1.13	1.03	0.088	0.048	25.0	11.7
,,	D	1.421	1.441	1.33	1.23	0·089	0.030	3.0	2.3
,,	F	1.154	0.935	1.28	0.94	0.100	0.085	18.0	14.2
,,	G	1.107	1.021	1.39	0.92	0.068	0.057	4.3	3.2

(1) Cotton-cane series. (2) Sann-cane series.

The results in Table V show that in the case of humus there is a fluctuating behaviour of soil types. The cotton cane series which have received 20000 lbs. of compost to cane crop have shown higher levels of nitrogen, available phosphate and organic carbon in all the soil types as compared to sann-cane series in which sann was used for green manuring. Compost thus appears to be more useful in improving the soil fertility than green manuring.

COMPOST NO-COMPOST SERIES

LONG RANGE EFFECTS OF COMPOST NO-COMPOST TREATMENTS ON SOIL CONDITIONS UNDER ROTATIONAL CROPPING OF SUGARCANE

This experiment (**2**,3,7) started in 1940, has been laid out according to simple randomised block design, with four treatments having plot size of 4 cents. each. In this experiment there are two main treatments—compost and no compost. The compost series receive 20,000 lbs. per acre of compost to every cane crop. Both the series received 300 lbs. of nitrogen to cane crop as top dressings in the form of sulphate of ammonia alone, cake alone, or mixture of both in proportions as 1:1, 1:2, and 2:1 of nitrogen. The variety Co. 419 has been grown throughout, the rotation being groundnut, sugarcane and winter sorghum.

(*i*) *Fertility studies*. With the completion of four cycles in 1952, soil samples upto 2′ depth were collected at the depths of 6″ each and were studied in detail for chemical, physical and microbiological characteristics by standard methods (9). The analytical results for the first two depths are given in Table VI.

The results show that application of compost has definitely improved the organic matter status of the soil. Humus content is more in all the plots in the compost treatment as compared to those in no compost treatment. Sulphate of ammonia alone has reduced humus content more than control (without nitrogenous top dressing). Compost has also helped in increasing the organic carbon of soil in all the plots. Total nitrogen content is higher in compost treatment than no compost treatment except in the case of sulphate of ammonia and oil cake mixture in the ratio of 1:1. The availability of P_2O_5 and K_2O is higher in compost treatment than with no-compost treatment. The data for nitrate nitrogen indicate that compost treatments in general maintain higher nitrate nitrogen contents of soil.

Application of compost has reduced the free lime content of soil in the top horizons to a certain extent, in general, indicating that the profuse evolution of carbon di-oxide under the compost series has resulted in larger removal of free lime. The comparison between the pH levels show that the surface soil has slightly lower pH than the subsoil. The trend is just the reverse with no-compost plots. It is presumed that increased aggregation of the soil due to compost (humus) application has improved drainage conditions of soils and decreased soil alkalinity. The exchangeable calcium, however, does not show any marked difference between the compost and the no-compost treatments.

TABLE VI

LONG RANGE EFFECTS OF COMPOST NO COMPOST TREATMENTS ON SOIL CONDITIONS UNDER ROTATIONAL CROPPING OF SUGARCANE

		With compost –20,000 lbs. per acre							Without compost						
Treatment	Depth	Humus %	Organic Carbon %	Total Nitrogen %	C/N Ratio	Nitrate Nitrogen	Av. P_2O_5	Av. K_2O	Humus %	Organic Carbon %	Total Nitrogen %	C/N Ratio	Nitrate Nitrogen %	Av. P_2O_5	Av. K_2O
						...mgms/100 gms. soil							...mgms/100 gms soil		
No nitrogen top dressing (No. N. T. D.)	0-6″	1.33	0.90	0.068	13.07	0.81	9.34	30.7	0.99	0.84	0.064	13.06	0.86	6.43	26.9
	6-12″	0.99	0.86	—	—	0.38	7.14	22.3	0.84	0.72	—	—	0.80	3.06	24.0
N. T. D. Cake alone	0-6″	1.20	0.97	0.066	14.22	0.91	8.04	35.2	1.01	0.82	0.059	13.90	1.03	6.17	27.1
	6-12″	1.06	0.96	—	—	0.73	6.09	18.8	0.91	0.76	—	—	0.51	5.58	22.9
N. T. D. Sulphate A.mmonia alone	0-6″	1.14	0.89	0.069	12·94	1.09	8.51	34.3	0.92	0.82	0.056	14.40	0.86	5.21	27.5
	6-12″	1.08	0.89	—	—	0.75	7.15	24.1	0.80	0.81	—	—	0.65	4.87	30.3
N/ T. D. S/A : Cake as 1 : 1	0-6″	1.22	0.98	0.061	15.98	1.07	10.73	29.8	0.98	0.94	0.070	13.41	0.49	9.55	23.7
	6-12″	1.08	0.90	—	—	0.55	10.42	24.9	0.92	0.90	—	—	0.35	6.83	14.30
N. T. D. S/A : Cake as 1 : 2	0-6″	1.38	0.98	0.076	12.71	1.24	9.42	38.8	0.96	0.86	0.067	12.80	0.70	8.17	33.1
	6-12″	1.20	0.92	—	—	0.82	7.89	28.9	0.94	0.81	—	—	0.50	7.06	26.5
N. T. D. S/A : Cake as 2 : 1	0-6″	1.35	0.93	0.068	13.73	0.86	7.19	36.6	1.11	0.87	0.060	14·41	0.82	6.40	21.0
	6-12″	1.33	0.90	—	—	0.68	8.08	21.0	1.06	0.65	—	—	0.78	6.12	19.2

(ii) *Cumulative effect of compost* (*on soil condition*) *in relation to crop yields.* The yield data are presented below to bring out the cumulative effect of compost applications as a basal dose.

YIELD IN TONS PER ACRE OF SUGARCANE

Particulars	Basal manure	First cycle	Second cycle	Third cycle	Fourth cycle
1. Compost no-compost treatments with nitrogen top dressing	With compost*	17.52	16.62	13.20	16.15
	Without compost	18.30	12.79	10.98	9.47
2. Compost no-compost treatments (cumulatively)	With compost	50.68	39.04	36.47	43.41
	Without compost	48.39	32.63	30.31	28.81

*20,000 lbs. per acre.

The beneficial effects, produced by the compost on the physical, chemical and microbiological condition of the soil are clearly reflected on the yields. It is also observed from the yield data that under no nitrogenous top dressings, compost treatment yields better than no compost treatment. There is a cumulative effect of compost application as shown by the yields which do not differ much during the first cycle, but the difference becomes wider as the number of cycles increase. It is also found that the average yields with treatments receiving compost are higher than without compost for all the cycles and the difference in yields is wider with the increase in the number of cycles.

CONCLUSIONS

1. Sulphate of ammonia is advisable as a fertiliser for the alkaline soils of Deccan Canal tract. It helps in reducing the pH of the soil and is also beneficial due to the fact that the loss of nitrogen is the least with its application. Chillean nitrate is inferior in this aspect. Moreover, it tends to increase soil alkalinity.

2. As phosphatic fertiliser, superphosphate is better than either bone meal or basic slag. It is also observed that phosphatic fertilisers help nitrogen status of soil.

3. There is no remarkable difference between sulphate of potash and muriate of potash.

4. Farm yard manure is superior to other organic and bulky manures in maintaining the humus as well as the fertility status of soil.

5. In the fallow continuous cultivation as well as irrigation depletes humus status of soil.

6. Rotational system of cropping (crops other than sugarcane) is superior to continuous growing of the same crop in maintaining the fertility status of the soil.

7. A two year rotation of sorghum cotton seems to be the best in maintaining the fertility status.

8. Compost application has proved superior over sann-green manuring in improving fertility status of all soil types.

9. Crop response to phosphate manuring is better under sann-green manuring than compost application.

10. Application of compost as a basal manure proves beneficial to soil in building up the soil fertility and improving the humus status.

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DISCUSSION

Mr. C.N. Agarwal stated that wide variations were observed on the growth and quality of the sugar cane crop as influenced by the application of phosphatic fertilizers in different doses. He also wanted to know whether the application of phosphatic fertilizers had any significant effect on the sucrose content.

Mr. Gumashte pointed out that in soils deficient in phosphate, significant response was observed with the application of phosphatic fertilizers on yield alone and not on quality. But no such response was observed in soils rich in phosphate.

Dr. H. Evans said that even in soils with low phosphate status in British Guiana, there was no response when insoluble phosphate was applied ; but with the application of soluble phosphate as triple superphosphate the response was significant. Placement of phosphate produced no effect, where as surface dressings gave better results. Increased phosphate dressings to the soils did not bring about any corresponding increase in phosphorus content of the foliage.

Dr. S.C. Sen pointed out that definite correlations existed between the nitrogen and phosphate adsorptions by the cane plant. The proportion of nitrogen and phosphate absorption was found approximately to be 1 : 2 or 1 : 3. No response with phosphate application on cane was observed in Uttar Pradesh since phosphate in adequate quantities was usually applied through farmyard manure and oil cakes. In Bihar also the response with higher doses of phosphatic fertilisers was not significant, and most of it was fixed in the highly calcareous soils of North Bihar.

Dr. R. K. Tandon observed that the results obtained in the permanent manurial trials at Shahjahanpur did not tend to support Dr. Sen's statement regarding N:P balance.

Dr. Rege stated that sugarcane being a long-term crop continues to absorb nutrients for a period of about 4 to 6 months of its growth. The deficiency or adequacy of phosphate as indicated by the chemical analysis of soils was not likely to give a clear indication regarding response to the applied phosphates. During its long period of growth the unavailable phosphate in the soil becomes available to the crop, thus masking the effect of the applied phosphates.

Mr. Mohan Rao described that phosphate applications did not show any response, while spraying of dilute solutions of ammonium sulphate on leaves led to encouraging results.

In the absence of the author Dr. A.J. Mangelsdorf presented the following paper.

Paper

THE USE OF AQUA AMMONIA IN THE HAWAIIAN SUGAR INDUSTRY

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The Hawaiian sugar industry has supplied its nitrogen requirements largely from ammonium sulphate since the middle 1930's. The first major change in nitrogen fertilizers since that time is currently taking place. Ammonia dissolved in water, commonly known as "aqua ammonia", is rapidly replacing the other forms of nitrogen fertilizer used. Substantial savings in cost of material, cost of handling and cost of application have resulted in a relatively rapid shift to aqua ammonia.

The first bulk shipment of aqua ammonia arrived in Hawaii in December, 1953. In 1954, 47 percent of the 15,196 tons of nitrogen purchased by the 28 plantations was aqua ammonia. The bulk of the aqua ammonia has been used on irrigated lands where it has largely supplanted other carriers of nitrogen. It is applied both in irrigation water and by injection equipment.

APPLICATION IN IRRIGATION WATER

It has long been recognized that poor distribution of water in furrow irrigation resulted in uneven application of fertilizer dispersed in the irrigation water. Intensive studies were initiated in 1951 to evaluate the various systems of irrigation used on Hawaiian sugar plantations. The shortcomings of these systems with respect to specific types of soil and length and grade of line were investigated by means of radioactive materials and tracer techniques. These studies (1) have brought about modifications of lengths and grades of lines and volumes of water, resulting in better distribution of water. Good distribution of water is obtainable under long line systems of irrigation in relatively impervious soils. In highly permeable soils, it is impossible to obtain a good distribution of water and still keep erosion losses to a minimum. The objectives of these studies were to learn where reasonably satisfactory water distribution was being obtained and to encourage the application of aqua ammonia in irrigation water in these areas. Where water distribution was poor, application of aqua ammonia in irrigation water was discouraged.

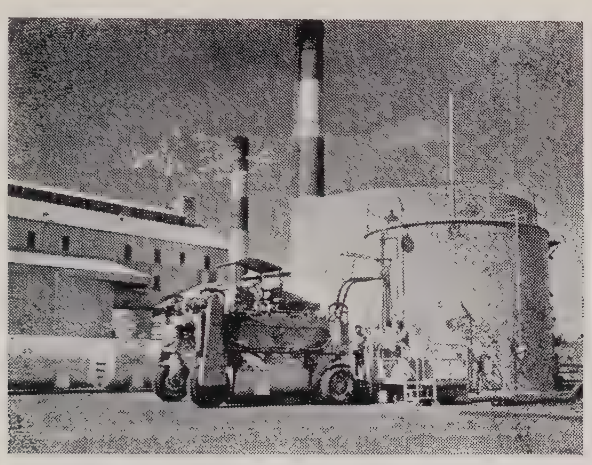

Fig. 1. Ewa Planation Company's 32,000 gallon storage tank and a small 1,800 gallon field tank below the materials carrier being filled with aqua ammonia. Courtesy Ewa Plantation Company.

Problems in the handling of aqua ammonia have been properly engineered. Aqua ammonia, prepared from anhydrous ammonia, containing 20-21 percent nitrogen, is pumped into tankers and shipped to Hawaiian ports. From the tankers it is pumped into large storage tanks and transported in tank trucks to the

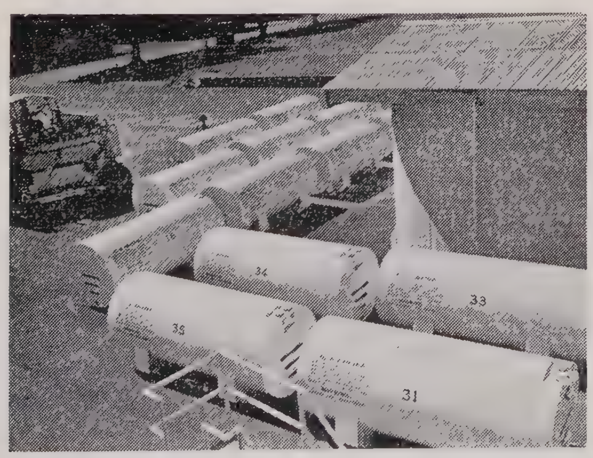

Fig. 2. Aqua ammonia field tanks designed for handling and distribution to the fields by a materials carrier. Courtesy Ewa Plantation Company.

plantation storage facilities. Figure 1 shows Ewa Plantation's 32,000 gallon storage tank and below the materials carrier an 1,800 gallon field tank being filled with aqua ammonia. Filling the tanks is a push-button operation. A special gauge automatically shuts off the flow from the storage to the field tank when the latter is full. Figure 2 shows field tanks specially designed for efficient handling by a materials carrier. When applied to the irrigation water, as shown in Figure 3, the aqua ammonia first passes through a metering box whose calibrated dispensing valves assure delivery of the exact amount desired.

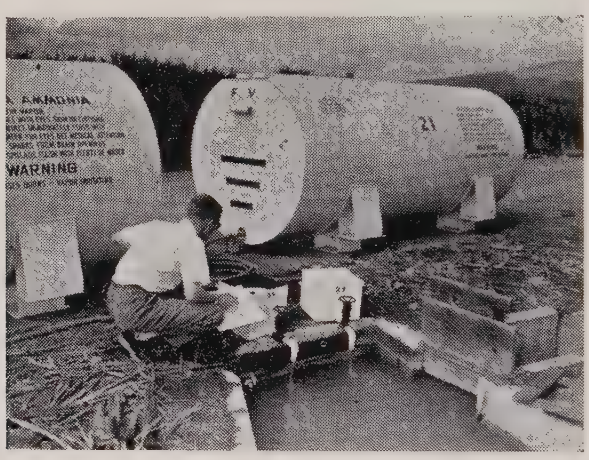

Fig. 3. Application of aqua ammonia in irrigation water at Ewa Plantation Company. Automatic controls regulate the flow from the portable field tank to the distribution ditch. Courtesy Ewa Plantation Company.

Effective distribution of nitrogen in the irrigation water down furrows 200 to 400 feet in length poses additional problems. To ensure optimum yields, adequate but not excessive amounts of nitrogen must be fed to each section of line. Inadequate nitrogen lowers cane tonnage, while excessive nitrogen results in higher cane tonnage accompanied by poor juice quality and lower sugar yields. The difficulties encountered in attaining a satisfactory distribution of nitrogen from aqua ammonia are not only associated with the peculiar physical and chemical properties of ammonia but are also inherent in the mechanics of spreading water in furrow systems of irrigation.

METHODS OF STUDY

Field and laboratory studies were initiated to determine the reasons for poor distribution in furrow irrigation and to study losses from volatilization and other processes. Field studies were made under a variety of soil conditions on different plantations with variations in rates of water flow and amounts of aqua ammonia. Water was applied to the furrows through calibrated Parshall flumes. A recording device provided a continuous record of water input. Ammonia was added to the irrigation water through a calibrated orifice at a constant head. Mixing flumes were used to ensure satisfactory blending of water and ammonia. Ammonia was applied at rates ranging from 40 to 100 pounds nitrogen per acre.

Stations for sampling the water were established at 50-foot intervals down the furrow, the first station being located at the point where the ammoniated water left the mixing flume. Samples were taken at each station at regular intervals throughout the irrigation.

Early in the study, samples representing various periods of flow were analysed separately in order to determine the constancy in concentration of ammonium at a particular station. Subsequently, a single composited sample was obtained at each station. Final samples were placed in tightly closed bottles for transport to the laboratory. Upon arrival, the samples were immediately treated with sufficient sulphuric acid to arrest nitrification and possible loss by volatilization.

To establish the profile distribution of nitrogen soil samples were taken in various increments to a depth of three feet, until preliminary data indicated that shallower sampling was satisfactoty. The samples representing the entire width of wetted furrow were taken immediately following the infiltration of the ammoniated water into the soil. The wet soil samples were placed in tightly covered moisture cans for transport to the laboratory. The samples were always analysed within 24 hours, and prior to analysis were kept at a temperature of about 10° C to minimize nitrification.

EXPERIMENTAL RESULTS

Ammonia concentration in relation to distance from flume. Ammonia concentration at any point down the furrow does not vary significantly during the period of irrigation. Table I shows the data from six furrows at two rates of ammonia application, with the application time divided into four parts.

TABLE I

AMMONIUM IN IRRIGATION WATER IN RELATION TO PERIOD OF FLOW—IN PPM NITROGEN

Period of flow Minutes	Line 1	Line 3		Line 5		Line 2			Line 4		Line 6			Av.
	50′	50′	100′	50′	100′	50′	100′	150′	50′	100′	50′	100′	150′	
0-20	25	24	23	23	23	45	43	42	56	57	52	46	44	39
20-40	25	29	28	23	23	46	41	41	63	60	51	51	49	41
40-60	31	26	26	22	23	55	52	51	55	56	53	50	47	42
60-80	25	24	26	24	24	43	45	44	52	54	59	51	51	40
Average	26	26	26	23	23	47	46	45	56	57	54	50	48	

Absorption of nitrogen from ammoniated irrigation water by the soil. The depth of ammonium penetration from aqua ammonia applied in irrigation water is of great practical importance. In dry irrigated lands, the soil surface is alternately wet and dry. This condition limits the extension of cane roots to the soil surface, thus temporarily placing the ammonia fixed at the surface out of reach. Profile distribution studies show that the aqua ammonia applied in irrigation water is held near the surface of the soil. In some soils the entire application is contained in the top three inches, with the bulk of the nitrogen in the surface inch. The results of studies on three widely-separated soils are shown in Tables II and III.

TABLE II

PROFILE DISTRIBUTION OF N RESULTING FROM AQUA AMMONIA APPLIED IN IRRIGATION WATER

Lahaina Family—HC & S			Lahaina Family—Waialua		
Distance from head of line Ft.	Depth In.	N Recovered* %	Distance from head of line Ft.	Depth In.	N Recovered* %
0-50	0-3	89	0-50	0-3	94
0-50	3-6	11	0-50	3-12	6
50-100	0-3	83	50-100	0-3	90
50-100	3-6	17	50-100	3-12	10
100-150	0-3	83	100-150	0-3	88
100-150	3-6	17	100-150	3-12	12
150-200	0-3	87	150-200	0-3	91
150-200	3-6	13	150-200	3-12	9
Mean	0-3	86	Mean	0-3	91
Mean	3-6	14	Mean	3-12	9

*Mean values for three replications.

TABLE III

PROFILE DISTRIBUTION OF N RESULTING FROM AQUA AMMONIA APPLIED IN IRRIGATION WATER

Molokai Family—Waipio Substation							
At 25'*		At 100'*		At 175'*		Mean	
Depth In.	N Recovered %	Depth In.	N Recovered %	Depth In.	N Recovered %	Depth In.	N Recovered %
0-1	53.2	0-1	66.0	0-1	49.5	0-1	56.2
1-3	26.6	1-3	10.2	1-3	41.2	1-3	26.0
3-6	10.4	3-6	15.4	3-6	9.3	3-6	11.7
6-9	3.5	6-9	2.3	6-9	0	6-9	1.9
9-12	3.5	9-12	2.3	9-12	0	9-12	1.9
12-24	2.8	12-24	3.7	12-24	0	12-24	2.2
24-36	0	24-36	0	24-36	0	24-36	0

*Distance from head of line.

These results are in harmony with the findings of Jenny, Ayers and Hosking (2) who, in laboratory studies with acid clay loams, observed a comparable retention of N from ammonia in the surface few inches of soil.

The ability of the soil to remove ammonia from ammoniated water must account in part for the decrease in concentration of nitrogen as the irrigation water flows down the furrow. Thirty-five tests were run to establish the relationship between concentration of nitrogen and distance from the head of the furrow. The data were analyzed in three groups, depending upon the initial concentration of ammonia in the water. Regressions for the three groups of data were all significant beyond the .01 level and show average decreases in nitrogen concentration of 21 percent from the head to the tail of the lines.

In big cane, conditions in the furrow are very different from those in young cane. A study was made of the effects of lodged cane with its accompanying blanket of trash on nitrogen distribution. Nitrogen was applied at two rates, 60 and 100 pounds N/acre, in year old cane. The results are shown in Table IV.

TABLE IV

N CONTENT AMMONIATED IRRIGATION WATER APPLIED TO 12-MONTH OLD CANE AT WAIALUA AGRICULTURAL COMPANY

Furrow* No.	Application of N	Concentration of N Initial	Concentration of N Final	Decrease in N	
	lbs.-acre	ppm	ppm	ppm	percent
1	60	49	26	23	47
2	60	43	30	13	30
3	60	50	26	24	48
Average	60	47	27	20	41
4	100	88	72	16	18
5	100	91	73	18	20
6	100	92	80	12	13
Average	100	90	75	15	17

*Length of furrows 200′.

These preliminary data indicate that a better nitrogen distribution can be obtained by applying larger quantities of nitrogen at one time than by splitting into two or more applications. These conclusions are not supported by the data obtained in trials with younger cane.

Effect of previous fertilization. The effect of previous fertilization on the concentration of ammonia in irrigation water was determined at Waialua Agricultural Company. Two furrows, whose previous treatments were identical except that one had received 50 pounds nitrogen from sulphate of ammonia and ammonium phosphate and 63 pounds nitrogen as sulphate of ammonia, respectively three months and one month previously, were treated with aqua ammonia in irrigation water. The results are presented in Table V. It is apparent that previous applications of nitrogen had little influence upon the concentration of ammonia in the irrigation water.

TABLE V

EFFECT OF PREVIOUS FERTILIZATION ON N CONTENT OF AMMONIATED IRRIGATION WATER

Distance from head of furrow Ft.	Unfertilized	Fertilized
	(N in p. p. m.)	
0	30	36
10	29	36
30	28	36
50	31	33
100	25	32
150	23	29
200	22	27
Decrease	8 (27%)	9 (25%)

Comparisons with other nitrogen carriers. Decreases in concentration of ammonia down the irrigation furrows prompted similar studies with other nitrogen carriers. Tests were installed comparing aqua ammonia with sulphate of ammonia, urea and nitrate of soda. Nitrogen from the various sources was applied at the rate of 40 lbs. N/acre. The averages of three tests are presented in Table VI.

TABLE VI

NITROGEN CONTENT OF IRRIGATION WATER IN RELATION TO FORM OF N CARRIER

Carrier	Distance from head of line Ft.	N* ppm	Carrier	Distance from head of line Ft.	N* ppm
Aqua ammonia	0	29	Urea	0	45
,, ,,	50	26	,,	50	43
,, ,,	100	25	,,	100	43
,, ,,	150	25	,,	150	43
,, ,,	200	22	,,	200	43
Decrease		7	Decrease		2
Ammonium sulphate	0	43	Sodium nitrate	0	42
,, ,,	50	41	,, ,,	50	41
,, ,,	100	41	,, ,,	100	39
,, ,,	150	40	,, ,,	150	41
,, ,,	200	—	,, ,,	200	41
Decrease		3(150′)	Decrease		1

*Average of three experimental results.

It is apparent from Table VI that a substantially greater decrease in nitrogen in the irrigation water occurred where aqua ammonia was used than when other carriers of nitrogen were applied. The magnitude of the decrease declined in the following order : aqua ammonia, sulphate of ammonia, urea, and nitrate of soda.

Causes of decreased ammonia concentration. Presumably nitrogen is removed from the irrigation water at the interface between the moving water and the surface of the furrow. The rate of removal depends upon a number of factors, including the pH and the percentage ammonia saturation of the surface soil layers, the permeability of the surface soil, and the degree of turbulence of the irrigation water. The finely divided soil particles and organic material that are suspended in the irrigation stream as well as the larger particles that drift along the furrow surface are considered important factors. They are often highly saturated with ammonia and must play an important role in the distribution patterns of nitrogen down the furrows. To determine the influence of suspended material on the concentration of nitrogen, irrigation water was intentionally muddied by stirring the surface of the furrow with hoes at several stations along the furrow while water samples were being collected in the usual manner. In one test, the water was muddied as it emerged from the mixing flume and water samples were taken at intervals of a few feet down the furrow for a comparatively short distance. With both tests, corresponding measurements were also made where there was no effort to increase the amount of soil material suspended in the water. The results are shown in Table VII.

TABLE VII

EFFECT OF SUSPENDED PARTICLES ON N CONTENT OF AMMONIATED IRRIGATION WATER

Waialua Family— Waialua					Molokai Family— Waipio		
Distance from head of line Ft.	N in ppm				Distance from head of line Ft.	N in ppm	
	Unmuddied		Muddied			Unmuddied	Muddied
	ppm	ppm	ppm	ppm		ppm	ppm
0	36	30	33	30	0	36	34
10	36	29	26	26	2	37	27
30	36	28	—	—	5	35	27
50	33	31	23	20	8	37	27
100	32	25	19	17	11	36	28
150	29	23	20	15	14	37	26
200	27	22	21	18	17	37	27
Decrease	9	8	12	12	Decrease	0	7
	25%	27%	36%	40%		0%	21%

*Average of two replications.

Increasing the quantity of soil particles in the irrigation water resulted in a marked decrease in ammonia concentration of the water. This decrease does not constitute a loss of nitrogen to the furrow but does minimize the chances of obtaining a satisfactory distribution of nitrogen.

Volatilization losses of ammonia from irrigation water. Since ammonia is a gas, volatilization losses were considered when the first application of aqua ammonia in irrigation water was made. In general, the losses were assumed to be small as long as one could not smell ammonia in the immediate vicinity of the area being treated.

To study losses under field conditions, a furrow with a slope of 1.8 percent was lined with a polyethylene plastic material which prevented contact between the irrigation water and the soil. As ammoniated irrigation water flowed down this lined furrow, concentrations of nitrogen in the water at various points along the line were determined in the usual manner. The data resulting from the first test are shown in Table VIII.

TABLE VIII

NITROGEN CONTENT OF AMMONIATED IRRIGATION WATER IN A PLASTIC-LINED FURROW, NEW HSPA SUBSTATION, EWA

Distance from head of furrow Ft.	N—in ppm I	II	III
0	90	95	101
50	92	93	100
100	90	91	97
150	88	91	98
200	86	90	94
250	86	89	92
300	85	89	91
Decrease	5	6	10

In the first two runs, concentrations of nitrogen at the end of the furrow were found to be 5 and 6 ppm (6%) lower than at the head of the furrow. In the third run, which, owing to the failure of the water supply, was not completed, the corresponding decrease was somewhat higher, or 10 ppm (10%).

The movement of water in the plastic-lined furrow differed markedly in two respects from the sort of flow that would be expected in the absence of the lining. With the lining, the water moved much more rapidly than would otherwise be the case (100′/min.), and the flow was more turbulent. To effect a condition corresponding more closely with that normally encountered in the field, while yet retaining the lining, a furrow in a field at Waipio was carefully graded to zero slope and lined with the same plastic material. The results of five runs in this furrow are shown in Table IX.

TABLE IX

NITROGEN CONTENT OF AMMONIATED IRRIGATION WATER IN A PLASTIC-LINED FURROW: WAIPIO SUBSTATION

Distance from head of furrow Ft.	N—in ppm				
	I	II	III	IV	V
0	93	99	96	100	100
30	94	99	94	96	97
60	93	96	95	97	98
90	91	96	96	94	97
120	93	94	95	94	98
150	93	93	92	94	94
180	91	93	91	94	96
210	92	93	93	93	97
Decrease	1 (1%)	6 (6%)	3 (3%)	7 (7%)	3 (3%)

The data reveal differences in nitrogen content between head and tail of the line ranging from 1 to 7 ppm. The mean of 4 ppm (4%) is a little lower than that observed in the previous test with a lined furrow. The smaller decrease in nitrogen concentration is attributed to the reduced turbulence of the water and to the shorter distance traversed.

The results of tests with plastic-lined furrows suggest that a portion of the observed decrease in the nitrogen content of ammoniated irrigation water, as employed in normal field fertilization, is the result of volatilization.

Controlled laboratory studies of volatilization losses. Volatilization losses from surface-applied aqua ammonia have been studied on a variety of sugarcane soils in closed systems using large desiccators. Air is forced continuously over

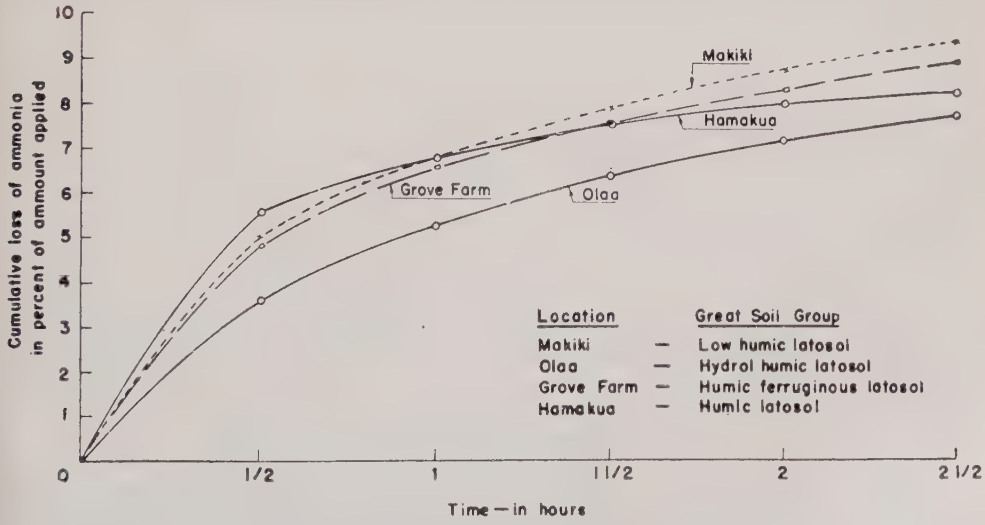

Fig. 4. Losses of ammonia from surface applications of aqua to moist soils.

the soil's surface and the ammonia in the air is trapped and titrated as it leaves the system. Losses of ammonia from surface applications to a variety of moist soils are shown in Fig. 4.

The curves of Figure 4 show losses ranging from about seven to ten percent from the wide variety of soils tested. When soils are air dry the initial losses from surface applications are shown to be larger than when these same soils are near field capacity (Figure 5). In the case of the slightly acid (pH 6.3) Waialua soil, the effect of moisture is greater than with the slightly alkaline (pH 7.5) Kahuku soil.

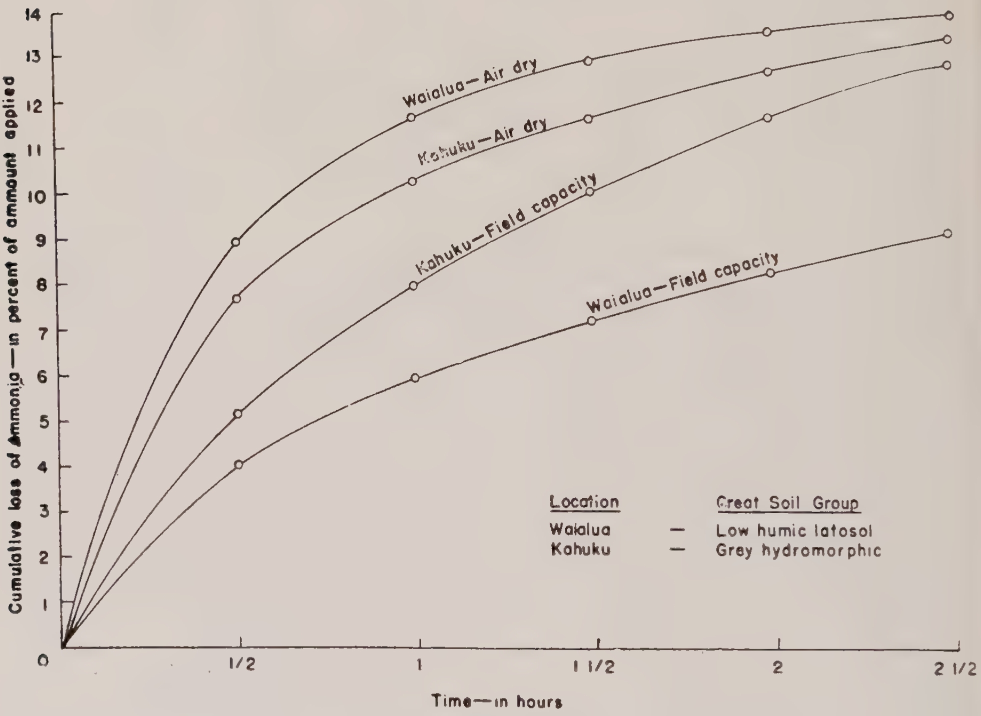

Fig. 5. Losses of ammonia from surface applications of aqua to soils in air dry condition and at field capacity.

A blanket of cane trash on the surface results in a larger volatilization loss. Controlled laboratory tests with Olaa soils show losses of ammonia from aqua applied to moist soil to be eight percent, while the loss jumped to 19 percent when there was a thin blanket of trash on the soil.

APPLICATION BY INJECTION EQUIPMENT

Only a small fraction of the total nitrogen purchased to date has been applied by injection equipment. Small scale application equipment was purchased for the initial trials on the unirrigated plantations. Problems of aqua placement, quantities required, corrosion, pump requirements, etc., were covered in some detail prior to the construction of the larger machines now in operation.

Placement studies. Surface applications of aqua ammonia were rejected on the basis of the first field trials. Chemical tests using "blotter" techniques with indicators showed that the losses of ammonia from surface applications on the cane line were excessive. The lower leaves of the young cane were severely burned from the volatilization losses. Applications on wet soils showed marked reduction in the loss of ammonia (Fig. 5) but were still high enough to warrant placement in the soil.

Volatilization losses from sub-surface placements have been very low. Detailed studies have shown a high percentage of ammonia adsorption by the soil even with placements as close as one inch to the surface. Placements two to three inches in depth are recommended for maximum efficiency of aqua ammonia applied. The ammonia spreads in all directions from the point of contact. The volume of affected soil varies with soil type and particularly with its porosity. In the heavier clay soils studied to date, the maximum zone of influence lies in a sphere five inches in diameter. The pH changes in the zone of application are appreciable. With applications up to 200 lbs. N/acre in bands, the pH has risen from 5.0 to as high as 9.2. Three months after application, the centres of the treated zone still have a pH of 7.5 to 8.0. In the zone of application, root systems of cane plants appear to be temporarily affected. Since sugarcane normally has a vigorous, widespread root system, the small percentage of roots affected by band placements of aqua does not appear to limit growth materially. Early in 1954, applications of aqua ammonia were made with the seed cane on the planting machine at Kahuku Plantation. The losses of ammonia were negligible when it was applied just ahead of the covering device on the planter. This operation has now been adopted as plantation practice at Kohala Sugar Company, and others are contemplating its use.

The bulk of the aqua ammonia applied by injection equipment has been used in connection with ratooning operations. Figure 6 shows the injection equipment used on Kohala Sugar Company's unirrigated fields. The aqua ammonia is applied through ground-driven positive displacement pumps mounted on a D-6 tractor. A clutch-operated transfer pump, driven by the rear power take-off, is used to fill the two 75-gallon tanks.

Figure 7 shows the two-row subsoiling and fertilizing machine used in ratooning operations of irrigated fields at Wailua Agricultural Company. The fertilizer is placed on both sides of two 5½ foot rows, 39 inches apart. Aqua ammonia and solid potash and phosphate fertilizers are applied immediately after harvest. The tractor is equipped with positive displacement piston-type pumps driven from a starr wheel which takes its power from the caterpillar tracks. The solid fertilizer is metered by a scroll arrangement driven by a gear train through the starr wheel. The tractor has two fertilizer hoppers that hold 700 pounds each and two aqua

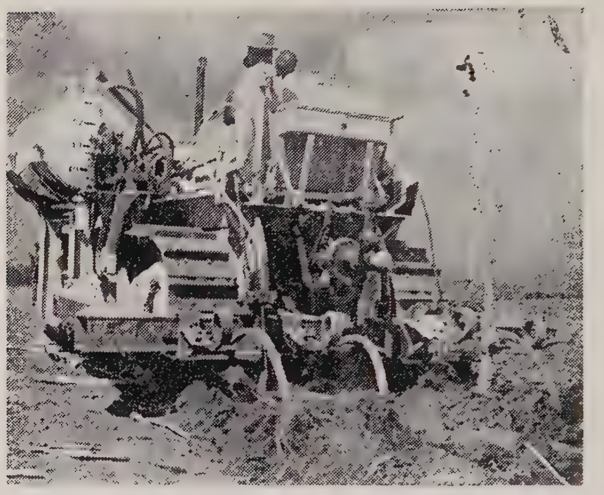

Fig. 6. Application of aqua ammonia by injection equipment on un-irrigated fields at Kohala Sugar Company. The aqua is applied through ground-driven positive displacement pumps mounted on a D-6 tractor. A clutch-operated transfer pump, driven by the rear-power take-off, is used to fill the two 75-gallon truck tanks. Courtesy Kohala Sugar Company.

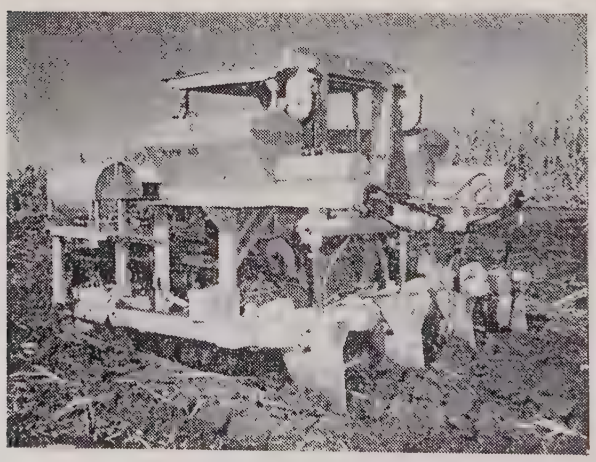

Fig. 7. Application of aqua ammonia and solid fertilizers at ratooning in irrigated fields at Waialua Agricultural Company. The liquid and solid fertilizers are applied on both sides of two cane rows and the rate of application isgeared to the speed of the tractor. This machine normally covers 5 to 6 acres per 8-hour day. Courtesy Waialua Agricultural Company.

ammonia tanks with 55 gallons each. This machine covers five to six acres per eight-hour day.

Onomea Sugar Company's four-row, two-way machine with full hydraulic control applying aqua ammonia on both sides of each cane row at approximately one inch depth is shown in Figure 8.

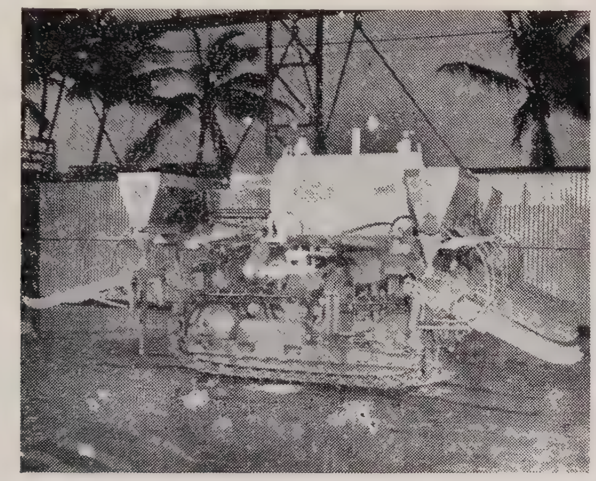

Fig. 8. Onomea Sugar Company's new fertilizer machine: a four-row two way machine with full hydraulic control applying aqua ammonia on both sides of each cane row from two 200-gallon tanks. Four stainless steel hoppers each holding 500 pounds muriate of potash deliver the potash applied to the surface of each cane line. Courtesy Onomea Sugar Company.

The need for potash fertilizers along with nitrogen at different periods in the growth of the crop postponed the acceptance of aqua ammonia on many of the unirrigated plantations. Muriate of potash, the form in which potash is used in the sugar industry, has a low solubility in water. This low solubility resulted in a shift from foliar sprays of urea in 1951 and 1952 to air application of granular solid fertilizers of urea and granular muriate of potash for second-season fertilization. The unirrigated plantations accepted the challenge to engineer. equipment that would apply both liquid nitrogen fertilizer and solid potash fertilizer Four stainless steel hoppers, each holding 500 pounds of muriate of potash, make it possible to apply 200 pounds/acre to ten acres without reloading. The muriate of potash is applied to the surface of each cane line. The position and depth of placement of aqua ammonia are adjustable, the ammonia being applied back of the swept-back shanks designed by Brea Chemical Company. Two 200-gallon aqua ammonia tanks hold enough liquid nitrogen to apply 75 pounds N/acre to eight acres without reloading. The rate of aqua and potash applications can be varied by simple adjustments of the pumps and slides on the hoppers. A rate of six acres per hour has been attained without time out for refilling. The machines are supplied with fertilizer from a truck-trailer supply unit which holds 1200 gallons of aqua ammonia in the flat tank and 30 bags of muriate of potash on top.

SUMMARY

The Hawaiian Sugar Industry has made a rapid conversion to the use of aqua ammonia because of substantial savings in cost of material, methods of handling, and application.

The bulk of aqua ammonia purchased in 1954 and 1955 was applied in irrigation water on the irrigated plantations. The problems involved in achieving a satisfactory distribution and utilization of aqua ammonia are discussed in as much detail as accumulated scientific facts permit. Results of current studies may modify the methods of application, but every effort will be made to use the cheaper liquid nitrogen.

Application of aqua ammonia by injection equipment on both unirrigated and irrigated plantations is progressing satisfactorily. Examples of equipment now in use on Hawaiian plantations are discussed.

ACKNOWLEDGMENT

The authors wish to acknowledge the assistance of R. B. Campbell, H. H. Hagihara, island representatives of HSPA and staffs of the various plantations who participated in this study.

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DISCUSSION

Dr. Arakeri wanted to know how distribution of aqua ammonia was regularized from furrow to furrow. In reply, Dr. Mangelsdorf stated that this could be regularized with the irrigation water ; but variations in the concentration of ammonia were observed from furrow to furrow.

In the absence of the author the following paper was taken as read.

Paper

A PRELIMINARY REPORT OF SOIL COMPACTION STUDIES OF LOUISIANA CANE SOIL

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Field Crops Research Branch, Agricultural Research Service, United States Department of Agriculture.

For over a century sugarcane was grown in Louisiana with the use of little mechanical equipment. Relatively light weight mechanical loaders began to replace hand loading about 1900. The modern rubber-tired cane tractor, introduced in 1931, gradually replaced mules and light cultivating implements (1). The modern cane harvester was developed in 1938. Heavy equipment came into general use during the Second World War, because of a great reduction in the supply of available labour ; this led to the development of heavy mechanical harvesters and loaders. Some growers have expressed concern about the possibility of soil compaction, and its effect on the growth of the cane, resulting from the long continued use of this heavy cultivating and harvesting equipment, especially under the unfavourable soil moisture conditions that often occur during the harvest season.

Soil compaction studies included in this report will serve as a basis for more extensive studies pertaining to plant-soil relations. This broad study may involve observations of the effects of soil conditions on root development and on plant growth, and the varietal interaction to different soil conditions. It was believed that a preliminary study should be made to establish whether artificial compaction had occurred and to determine the presently existing extent of soil compaction in the cane fields. Accordingly, soil compaction studies were started in the spring of 1954 to determine whether artificial compaction had occurred in the cane fields, and, if so, to measure the extent of the increase in soil compaction. It was recognized that an increase in soil compaction would not necessarily be a result of the use of heavy mechanical equipment only, since compaction might also have resulted from the mules and lighter cultivating equipment used before tractors and harvesters came into general use.

Other studies designed to lead to the improvement of soil physical conditions for crop production, development of methods of deepening the effective rooting zone of crop plants, and improvement of air-water relationship and water movement in soils are now being conducted as a joint undertaking of the Soil and Water Conservation Research Branch of the United States Department of Agriculture and the Louisiana Agricultural Experiment Station. Most of their work reported involved studies with cotton on soils in north Louisiana ; some data were also reported with corn on soils near Baton Rouge. Deep tillage experiments have been started on soils in the sugarcane area of Louisiana.

Light and heavy soils in Terrebonne Parish, located in the south-eastern part of the sugarcane area of Louisiana, were used in this study. The light soils used were Commerce very fine sandy loam and Mhoon silt loam ; the heavy soil was Sharkey silty clay. Commerce very fine sandy loam and Mhoon silt loam are quite similar. although the Commerce type affords somewhat better drainage. At the 8-12 inch depth sampled for this work, the Commerce and Mhoon soils are dry, friable silt loams, essentially structureless, and slightly acid to slightly alkaline. The Sharkey soil at this depth is mildly alkaline clay, plastic when wet, hard when dry. Samples at the 8-12 inch depth were used, since this layer is below the normal depth of plowing and would probably represent the zone of greatest compaction.

Samples of soil at the 8-12 inch depth used for the volume weight determinations were taken by digging a horseshoe-shaped pit about 14 inches deep and carefully breaking out the centre portion of undisturbed soil, taking precautions to avoid artificial compaction of the 8-12 inch layer. Blocks of soil weighing about 500 grams were used for the volume weight determinations. These determinations were run in triplicate, using the paraffine method in which the volume of the sample is determined by weighing both in air, and suspended in water. All volume weights reported in this paper are expressed in grams per milliliter.

In order to determine the naturally occurring compaction in the virgin subsoils, samples were taken on both light and heavy soils, under different moisture conditions, from areas near cane fields, known to have been uncultivated for a great number of years, and therefore believed to be uncompacted artificially. On the light virgin soil, 75 volume weight determinations were made. From these data, a curve was constructed from the calculated formula, $Y = 1.7736 - .01552\,X$, where Y = volume weight, and X = %moisture in the soil at time of sampling. This curve had a highly significant correlation coefficient of -0.639. On the

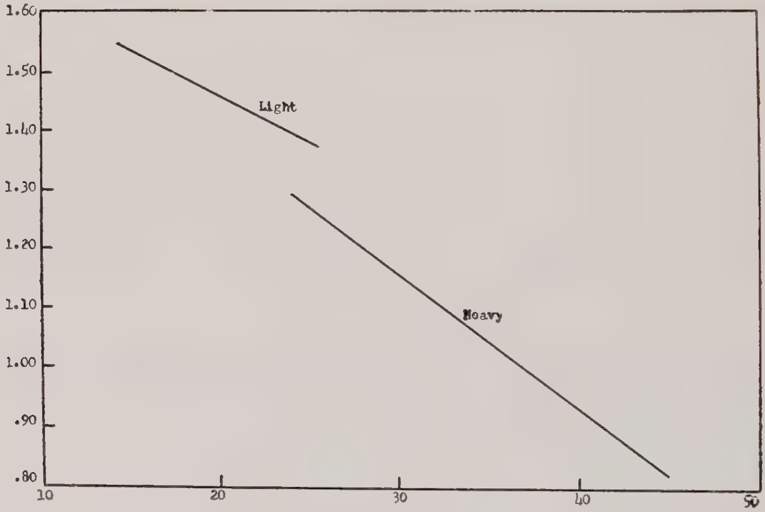

Fig. 1

heavy virgin soil, 42 volume weight determinations were made. From these data, a curve was constructed from the calculated formula, $Y=1.8347-.02244\ X$, where Y=volume weight, and X=%moisture at time of sampling. This curve had a highly significant correlation coefficient of —0.975. These two curves are shown in Figure 1.

Upon examining these curves, it was obvious that the volume weight of these subsoils decreased as the percent moisture at time of sampling increased, probably due to shrinkage of the soil as it dried. Therefore, in order to compare the naturally occurring compaction of the virgin soils with the compaction of the field soils, volume weight data were calculated to a constant moisture at time of sampling basis. For the light soils, 20%moisture at time of sampling was used, and for heavy soil, 30%, since these were about average values for the percentages of moisture present in the samples at the time they were collected.

On field soils on plantations where heavy cultivating and harvesting equipment were in general use,77 volume weight determinations were made on light subsoil and 56 on heavy subsoil, from samples collected at the 8-12 inch depth. Summarized data are shown in Table I.

TABLE I

VOLUME WEIGHT OF VIRGIN AND FIELD SUBSOILS

Soil	Number of determinations	Range of Volume Weight	Average Volume Weight
Light soil (Virgin)	75	1·38—1·56*	1·46*
Light soil (Field)	77	1·36—1·60*	1·50*
Heavy soil (Virgin)	42	1·08—1·22†	1·16†
Heavy soil (Field)	56	1·18—1·31†	1·23†

For light field soil, the average increase in volume weight as compared to virgin soil must be 0.03 to be significant at the 0.05 level. 50% of the light field soils examined showed increases equal to, or greater than, this value. For heavy field soil, the average increase in volume weight as compared to virgin soil must be 0.02 to be significant at the 0.05 level. All of the heavy field soils examined showed increases equal to, or greater than, this value. Thus the average increases in compaction, expressed as volume weight, are small but are significant for both the light and heavy subsoils. Assuming a specific gravity of 2.65,the average reductions in total pore space amounted to 1.5% for the light field soil as compared to the light virgin soil, and 2.6%for the heavy field soil as compared to the heavy virgin soil.

In order to determine the effect of subsoiling on yields of cane and sugar per acre, 5 field experiments were conducted in 1954 on Mhoon silt loam to silty clay loam. Subsoiling was done in March, using a single knife colter midway between the cane rows, set to a depth of about 16 inches. A small shovel, about

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* Calculated on the basis of 20% moisture in the sample as taken in the field.

† ,, ,, ,, ,, ,, 30% ,, ,, ,, ,, ,, ,, ,, ,, ,,

3 inches wide, was bolted to the end of the knife colter. This operation had no significant effect on yields of cane and sugar per acre, as shown in Table II.

TABLE II

EFFECT OF SUBSOILING ON YIELDS OF CANE AND SUGAR PER ACRE

Experiment Number	Number of replications	Not Subsoiled		Subsoiled	
		Tons of cane per acre	Pounds of sugar per acre	Tons of cane per acre	Pounds of sugar per acre
1	3	27·84	4265	26·56	4266
2	3	27·54	4561	28·00	4544
3	10	31·23	4635	30·88	4558
4	4	25·84	3625	26·19	3889
5	6	26·58	5335	25·27	4968
Weighted Averages	26	28·51	4590	28·03	4514

Expt. No. 1 : C.P. 36/105 plant cane on Mhoon silt loam to silty clay loam.
Expt. No. 2 : C.P. 44/101 plant cane on Mhoon silt loam to silty clay loam.
Expt. No. 3—4 : C.P. 44/101 first stubble cane on Mhoon silt loam to silt clay loam.
Expt. No. 5 : C.P. 44/101 first stubble cane on Mhoon silt loam.

The efficiency of a subsoiling operation is partially dependent on the structural quality of the subsoil. The water stability (resistance to slumping or slaking) of the aggregates in the subsoil is an important phase of its structural quality. Water stability of the surface soil usually deteriorates when continuously used for clean tilled crops. It was felt desirable to determine the effect of long continued cultivation on the water stability of the subsoils. Accordingly, the water stability of virgin and field subsoils was determined on a limited number of the above samples, using the wet-sieving apparatus and method of Bryant, Bendixen, and Slater (2).

Summarized data are shown in Table III.

TABLE III

WATER STABILITY OF VIRGIN AND FIELD SUBSOILS

Soil	Number of determinations	Range of water stability %	Average water stability %
Light soil (Virgin)	6	58·5—92·5	83·4
Light soil (Field)	18	16·0—78·8	46·3
Heavy soil (Virgin)	4	95·6—96·4	96·0
Heavy soil (Field)	13	78·4—94·0	88·6

The average reductions in water stability of both the light and heavy field subsoils were highly significant as compared to the virgin subsoils.

SUMMARY

Studies of soil compaction at the 8-12 inch depth on cane soils in Terrebonne Parish, Louisiana, showed that a small but significant degree of artificial compaction had occurred in both the light and heavy soils. This was accompanied by a correspondingly small decrease in percent total pore space. Water stability of the subsoils was significantly reduced in the cultivated soils. In field experiments conducted in 1954, subsoiling with a single knife colter midway between the cane rows did not significantly affect yields of cane or sugar per acre. However, the effect of all of these changes in the subsoils on growth of cane has not been determined.

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In the absence of the author the following paper was presented by Mr. N. K. Das.

Paper

NATURE OF THE SOIL AND THE CHEMICAL COMPOSITION OF THE CANE JUICE IN RATIONALISING VARIETAL RECOMMENDATIONS

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AND

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Yield of sugarcane variety and its sucrose content have formed so far the main basis for selection and distribution of cane varieties. No attention has been given to the amount of minerals present in the soils for which the variety is recommended and that removed by sugarcane varieties growing on them. It was erroneously thought that the mineral nutrients removed by a cane crop are negligible (Prinsen Geerligs. 1924). That this does not happen under most conditions, more so in India where the soil reserve is already too low to be exploited without discrimination, is now too well known. Growing of high yielding sugarcane hybrids, which remove more nutrients per acre than the low yielding indigenous varieties, puts great strain on the reserve of nutrients present in the soil. It is also increasingly felt that the soils which once supported good sugarcane crops do not give the same yields as they used to be before. Also there is a slow but marked deterioration in the quality and disease resisting capabilities of cane varieties.

This paper suggests an alternative approach to the problem of breeding and selection of cane. It is thought that the amount of nutrients present in the soil and that removed by a cane variety must be considered to keep pace with the nutrient uptake of the succeeding cane crops. Therefore from this point of view, it may be proposed that the planning for distribution of cane varieties may take into account the nutrient minerals present in the juice of the variety of cane, as well as those of the soil of tract for which the variety may be recommended.

A scheme on soil studies of the sugarcane growing tracts of Uttar Pradesh was taken up jointly by the Government of Uttar Pradesh and the Indian Council of Agricultural Research in 1942. The district of Gorakhpur, which has the highest concentration of sugarcane factories and cane development zones in Uttar Pradesh, was selected for this work. The nature of the soils, performance of different cane varieties in different soil tracts, manurial requirements of the varieties under different soil conditions and quality of cane juice as influenced by different manurial doses formed the chief items of study.

In the course of the investigation of the problems mentioned above, the composition of the ash of cane juice was determined by the methods given by Spencer (1929). The ash was dissolved in 2-Normal Nitric acid and was kept in containers separately for each variety and for each soil type. Different cane varieties growing on cultivators' fields were sampled during the months of December, January, February and March for analysis, a period when cane is usually crushed in sugarcane factories. The nitric acid extracts from each variety in a soil type were combined together to determine the composition of ash. This work was conducted over three sugarcane seasons. The following gives an account of the soils on which the mineral contents of the juice of three varieties of sugarcane growing on them were determined.

SOILS

Soils of the cane growing areas of this district have been divided into three pedological types by Agarwal and Mukerji (1952). These are called types 1, 2 and 3 and have the characteristics mentioned below :

Type-1 : Calcium soils with large reserve of lime.

Type-2 : Leached calcium soils with large Calcium Carbonate accumulation at the bottom of the profile.

Type-3 : Degraded Calcium soils free of carbonate, and showing signs of formation of an unsaturated exchange complex.

The fertilizer requirements and varietal adaptability of these soil types have been described by Mukerji, Agarwal and Mukerji (1946).

DIFFERENCES DUE TO VARIETIES

Performance of different varieties of cane was tested in each of these soil types by crop cutting experiments. Annually a number of experiments were so conducted, spread over about 180 villages in ten Cane Development Zones. 360 sample cuts in the first year, 1800 sample cuts in the second year snd 2160 sample cuts in the third year, totalling 4320 sample cuts in all, were taken into account. In three cane seasons, canes from 30 Cane Development Zones were tested for mineral contents in the juice. Juice from three cane varieties, viz., Co. 370, Co. 356 and Co. 313, from each soil type were obtained and analysed each year for major minerals like calcium, potash and phosphate contents in the ash. Table I gives a consolidated summary of the three cane varieties in three soil types of Gorakhpur district.

TABLE I

SHOWING THE UPTAKE IN JUICE OF CALCIUM, POTASH AND PHOSPHATE FROM DIFFERENT TYPES OF SOIL BY THREE SUGARCANE VARIETIES (1941-44)

Soil Type	Variety											
	Co. 370			Co. 356			Co. 313			Average		
	CaO %	P_2O_5 %	K_2O %	CaO %	P_2O_5 %	K_2O %	CaO %	P_2O_5 %	K_2O %	CaO %	P_2O_5 %	K_2O %
Type-1	0·034	0·021	0·24	0·037	0·032	0·271	0·028	0·02	0·23	0·033	0·024	0·246
Type-2	0·036	0·028	0·10	0·034	0·093	0·109	0·042	0·045	0·088	0·037	0·055	0·099
Type-3	0·056	0·055	0·15	0·068	0·060	0·130	0·041	0·084	0·130	0·055	0·066	0·136

It may be seen that an average cane crop absorbs calcium maximum from type-3 soils, as compared to type-1 or type-2. Type-3 soils are degraded calcium soils. The calcium reserve is already low, and with the growing of cane unsaturation may still go up further. It may, therefore, perhaps be better to plan distribution of a variety of cane whose calcium requirement is lowest to check soil deterioration with respect to lime, Co. 313 seems to be a variety, whose calcium requirement is lowest on this soil type and it looks this may be preferred over the other two varieties if its yield is not abnormally low.

Maximum phosphate absorption by cane takes place in type-2 and type-3 soils, and least in type-1 soils. Manurial experiments conducted with sugarcane in type-2 soils, indicate a significant response in yield per acre to an application of phosphates. Phosphate content of type-2 soils is also low. The response of sugarcane to an application of phosphate suggests that the luxury removal of phosphate by sugarcane varieties may lead to further phosphorus depletion in soils resulting in loss of cane per acre as well as quality. Co.370 has been found to be economical in its phosphate requirement in this tract and may, therefore, be preferred over others in varietal distribution for the areas having type-2 soils. Soil phosphorus is moderate in type-3 soils, but in view of the comparatively large amounts of phosphates removed by a crop growing on them, we may have to supplement it at a later date if sugarcane yields are to be maintained satisfactorily. The planning of varietal distribution on this soil type, therefore, should take into account this factor of phosphate absorption.

Potash has been found to have been absorbed maximum from type-1 soils, followed by type-3 and type-2 soils. The potash content in soils has been found to be highest in type-3 followed by type-2 and type-1 soils. The varietal distribution for type-1 soils should, therefore, depend mostly on such varieties, whose potash requirements are not abnormally high. All the three varieties tested come within this category and one of them could be recommended for distribution depending on its yield performances.

DIFFERENCES DUE TO MANURES

To see how manuring in these three types of soils may affect the uptake of nutrients, statistically designed manurial trials with three doses of phosphates in all combinations, in six replications on a randomised block design, were conducted one in each of the soil types for three cane seasons.

Table II gives the composition of ash of juice of cane from different treatments averaged over three cane seasons in three soil types.

TABLE II

SHOWING EFFECT OF COMPOSITION OF JUICE DUE TO DIFFERENT LEVELS OF MANURING IN THE THREE SOIL TYPES (1941-44)

Level of N	Level of P	CaO Type 1	CaO Type 2	CaO Type 3	P_2O_5 Type 1	P_2O_5 Type 2	P_2O_5 Type 3	K_2O Type 1	K_2O Type 2	K_2O Type 3
No	P_0	0.046	0.044	0.044	0.027	0.054	0.063	0.31	0.114	0.14
	P_{40}	0.039	0.034	0.049	0.035	0.031	0.063	0.30	0.118	0.15
	P_{60}	0.039	0.034	0.055	0.012	0.023	0.062	0.26	0.134	0.15
Average for N_0		0.041	0.037	0.049	0.025	0.036	0.063	0.29	0.122	0.15
N_{40}	P_0	0.033	0.029	0.062	0.021	0.035	0.053	0.29	0.109	0.14
	P_{40}	0.033	0.040	0.049	0.019	0.023	0.042	0.30	0.146	0.13
	P_{60}	0.035	0.038	0.059	0.021	0.020	0.045	0.29	0.155	0.14
Average for N_{40}		0.034	0.036	0.057	0.020	0.026	0.047	0.29	0.137	0.14
N_{60}	P_0	0.036	0.032	0.055	0.018	—	0.052	0.31	0.133	0.13
	P_{40}	0.034	0.033	0.071	0.015	0.026	0.049	0.29	0.130	0.12
	P_{60}	0.033	0.048	0.062	0.015	0.020	0.040	0.26	0.130	0.11
Average for N_{60}		0.034	0.038	0.063	0.016	0.023	0.047	0.26	0.131	0.12
Average for	P_0	0.038	0.035	0.054	0.022	0.044	0.056	0.30	0.191	0.14
Average for	P_{40}	0.035	0.036	0.056	0.023	0.027	0.051	0.30	0.131	0.13
Average for	P_{60}	0.036	0.040	0.059	0.016	0.021	0.019	0.27	0.140	0.13

In regard to absorption of lime it may be noted that whereas in type-1 and type-2 soils addition of nitrogen has not increased lime absorption, its application both at N_{40} and N_{60} levels has appreciably increased uptake of calcium in the juice in type-3 soils. This factor is further aggravated due to the increased tonnage of cane obtained as a result of nitrogenous fertilization in type-3 soils. Although addition of phosphates did not materially increase calcium removal from the soil the evidences point to a slightly higher trend in type-2 and type-3 soils. Thus manuring with nitrogen to increase yields may further cause depletion of calcium in type-3 soils by virtue of its higher absorption in greater tonnage of canes removed in harvests. This supports the suggestion made earlier that only such cane varieties may be recommended for this soil tract, which have low lime demands upon the soil in order to prevent undue lime depletion in soils already poor in this ingredient.

With regard to removal of phosphates in canes, it appears that manuring with either nitrogen or phosphorus does not increase absorption of this ingredient in any of the three soil types studied. In every case manuring has decreased the percent content of phosphates in the ash of the juice. In type-2 soils, which are responsive to both nitrogen and phosphatic fertilization, application of nitrogen has decreased the phosphate removed by the crop per ton and phosphate has further decreased this absorption appreciably. A combination of nitrogen and phosphorus therefore, seems to be a good fertilizer practice for phosphate conservation in this soil type.

Absorption of potash by cane in type-1 soils where greatest potash is lost in cane cultivation seems not to be increased by application of nitrogen or phosphatic manures. We have, therefore, to depend entirely on selection of varieties in this soil type to take care of soil potash. There is, however, some increase in potash removal due to manuring in type-2 soils.

CONCLUSION

Thus it may be seen that in the distribution of varieties for a tract, which grows sugarcane intensively, besides the yield and quality, one must consider the varietal characteristics of selective removal of major mineral nutrients in relation to soil potentialities. Supplementing the nutrients so removed can always be advocated, but in practice it is not feasible to make even a fraction of the cane growers agree to supplement such removal, especially, when the additional expenditure so involved does not pay back immediately in the form of increased cane yields. The bad effects of this practice may become evident with long term use of soil with continuous growing of cane crops and their ratoons for generations. The only safe way, therefore, for continued prosperity of sugarcane cultivation from soil conservation lies in the release of varieties so planned as to suit the mineral nutrients set up of the different types of soils, and nutrients uptake thereon under the prevailing fertilizer practices. This factor may also be kept in view by plant breeders who may combine yield and quality characters with mineral uptake values of cane while producing improved cane varieties.

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CANE BREEDING SECTION

CANE BREEDING SECTION

Session—Friday, 27th January, 9-15 A.M.

SIR T. S. VENKATRAMAN, *Chairman*

The *Chairman* delivered the following opening address :

"We, sugar cane breeders, may be said to have had a comparatively easy time in the production of economic types. The genetic composition of the sugar cane plant which results in vide variations in the progeny and the fact that any selected type could be propagated vegetatively and hence comparatively quickly—without losing materially the characters for which it has been selected—have been responsible for this position. This has resulted in a tendency to neglect the fundamental and somewhat purely academic aspects, as compared to breeding work in other crops. In the absence of the slow and plodding work demanded from other crop breeders, sugar cane breeding to this day is largely a hit and miss method and useful results have depended directly on the number of chances that the cane breeder is able to include in his work. Signs are not wanting, however, to indicate that this situation could not last for ever. We are rapidly exhausting the possibilities from these methods and the industry is demanding quicker and better results.

It has been the practice to attempt some sugar cane breeding wherever sugar canes arrow and produce fertile seeds. Considerable benefit has resulted from such work in the past, and certain of the commercial canes have had their origin from this source—inclusive of commercial sugar cane plantations. While there is little doubt that such work should be continued in the future, there is need now for a Super-Sugarcane-Breeding-Station which would go into the fundamental aspects of the work, even if they are not likely to lead to early economic results. The sugar industry of the world is growing rapidly and is bound to be increasingly so in the future. There is, therefore, a growing need to introduce greater certainty into our breeding operations.

Considerable work has been in progress to simplify and render more efficient the minor techniques employed in cane breeding. Many problems yet remain to be fully solved, however, such as (1) inducing arrowing in varieties which we desire to employ as parents ; (2) inducing fertility in their sex elements ; (3) synchronising their time of arrowing to enable hybridisation between them. The work is difficult and the latest developments in science would need to be harnessed to the work. What is needed is really a probe into the life-processes of the sugar cane plant with particular reference to the origination and development of the sex elements and the complicated processes associated with fertilisation. The breeder should be able not only to watch and correctly interpret these processes but, if possible, influence and control them to the advantage of his work. All this is fundamental work not directly associated with the routine breeding work but needs to be undertaken in view of the long range results that may reasonably be expected to follow. To this category would belong attempts to cross the sugar cane with other genera or families with the object of getting into our new canes characters not available in the genus *Saccharum*. It may well be said that the sugar cane plant has co-operated remarkably with the human agent in such endeavours, as is evidenced by the large number of inter-specific and inter-generic hybrids that have already been obtained.

The *Saccharum spontaneum* expedition, now in progress at Coimbatore and the world collection of germ plasm that is collected in the United States are all right steps in this direction. To get the maximum benefit from such collections they will need to be quickly transferred to localities where they would arrow freely ; it is only when they arrow that it is possible, in the present state of our knowledge, to fully understand their genetic composition.

The procedure now adopted by most sugar cane breeding stations is firstly, to make the hybridisation, secondly, to raise seedlings from the hybrid seeds and thirdly, to send out setts or cuttings of such as are deemed likely to be useful in the different regions. This is done by a careful study of the characters of the seedlings or by comparison of these with the regional canes grown alongside of them at the breeding station. Now that the methods of growing canes from seeds are well known it is worth considering if it would not be cheaper and easier to send out the hybridised material in the form of fluff. Under this arrangement the seedlings will be growing from the very commencement under the environmental conditions of the regions. In the present state of our knowledge diseases are less liable to be transmitted through seeds than through cuttings. Sugar cane cuttings are ideal culture chambers for any virus or fungoid disease that may exist in the transmitted cuttings. In the past, sugar cane seeds thus sent out have yielded useful types at the other end. The Super Sugarcane Breeding Station of the future may probably elect to send out the material as fluff to the stations that support and finance the Super Station. It is presumed that the Super Station will be so equipped as to effect any crossing that may be desired by the regions supporting the Super Station.

The main aim of the sugar cane breeders hitherto has been—and rightly so—to breed better and yet better sugar canes from the sugar view point. In the language of the Javanese breeders it has been a continuous attempt at " nobilization". When one considers the pests and diseases that are prevalent in our sugar cane crops and the occasional failures of this crop over fairly large areas in certain years one is inclined to consider if there is not a need now for working into our new canes the wild types which have been responsible for giving us our present canes in cultivation. From the view point of having an assured crop through good and bad years, for ultimately cheapening sugar cane cultivation by extending it to less favourable and hence cheaper lands as also for securing greater resistance to prevailing pests and diseases such a "denobilization" in our sugar cane breeding programme would appear to be needed.

May I request the breeders assembled here to ponder over the above at their leisure and offer their comments either now or during the course of their observations on the papers that are to be discussed at our session".

The papers presented were then taken up. These were grouped by subjects and discussion was taken up at the end of each group.

Group I

BREEDING (General)

The Chairman invited Mr.N. J. King to present Mr. J.H. Buzacott's paper.

Paper

BREEDING CANES FOR HIGH SUGAR

J. H. Buzacott

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INTRODUCTION

The production of varieties of sugar cane having a high sugar content is not difficult but it is far from easy to develop such varieties which also produce the high tonnage of sugar per acre required of modern commercial varieties and at the same time to maintain their good agricultural characters. In Queensland the development of a higher sugar content even at the cost of yield of sugar per acre is an attractive economic proposition since the cost of labour for harvesting is relatively less per ton of sugar produced for the varieties with the higher sugar content. The increased monetary return to the farmer from growing high sugar varieties has recently been discussed by King (4).

Admittedly, yield of sugar per acre should be the ultimate requirement of the cane breeder. It is of little use however to produce a high yield of sugar per acre if the cutters will not harvest the crop, or if the variety will not germinate, or its cost of cultivation is too high on account of poor covering, or its milling properties are bad and render the cost of recovery of the sugar too high. Unfortunately the type of variety which suits one country does not necessarily suit the conditions required by any other country, and in consequence crosses which are successfully used to produce high sugar commercial varieties in one country may be useless in other countries because the varieties which result do not conform to the required type. Such factors as these have particularly to be studied in Queensland. With its manual harvesting and high cost labour it is imperative that varieties selected for commercial growth should remain erect at least under most growing conditions. In some countries such as Hawaii varieties which lodge comparatively early in life are desired for resistance to high winds and in any instance the two-year crop grown there would almost certainly lodge. At least portion of the cane grown on a Queensland farm should be capable of attaining high sugar by, or retaining its high sugar until, the late months of the year when many varieties have passed their sugar peak and tend to deteriorate. The Queensland crop is harvested on a one year basis and most of the cane is from 12—15 months old at harvest. This implies that some of the cane may be even younger than that and may in fact be only ten months old. In consequence it is highly desirable that varieties for early harvest should be able to develop a reasonably good sugar content by the time they are ten months old.

On the other side of the scale we have the fact that Queensland rainfall is generally well suited to a high sugar content. Even in those districts where a rainfall of over 100 inches per year is experienced such as Babinda, Innisfail and Tully most of the rain is confined to the first four months of the year. This rain normally falls in heavy precipitations lasting several days followed by a number of sunny days. Since the mills do not commence crushing until early in June, or at earliest the last week in May, and aim to have their crushing completed by the end of December, the heavy wet period generally falls outside the crushing season and there is an opportunity for the advent of sunny weather and some drying out of the soil to effect an increase in sugar content before harvesting operations commence. Also, although the Queensland crop is all grown close to the east coast, and in a coastal climate, there is quite a marked drop in temperature during the winter months which also possibly assists sugar development. This is in contrast to the essentially insular climate of countries like Mauritius and the West Indies where low temperatures are seldom experienced. At the Northern Sugar Experiment Station, which is situated in the Cairns district of Queensland, the average monthly minimum screen temperature recorded in the winter months of June, July and August for the past thirty years is 45.7°C., with a recorded minimum in some individual years of as low as 35°C. Considering that Cairns, at a latitude of 17°, is well within the tropics it will be understood that this figure is comparatively low compared to that recorded in many other tropical sugar-growing countries. It is not suggested that low winter temperatures, a restricted rainfall and sunny weather are the only factors which influence sugar content. If they were, then obviously the Bundaberg district should produce the highest sugar content in Queensland. In many years several mills within the tropics have a far lower record of tons of cane crushed per ton of sugar produced than does the Bundaberg area which is several degrees south of the Tropic of Capricorn.

Methods of payment for cane which operate in Queensland render it certain that there will be a continual demand from cane farmers for high sucrose cane varieties. It is of course doubtful if it is possible to continue indefinitely to produce varieties with both higher vegetative yield and a higher sugar content. The present indication of overproduction combined with high harvesting costs keeps up a demand for the utmost sugar content even to the detriment of total yield of sugar per acre. Largely from the method of payment for sugar cane on its sugar content, based on individual analysis, Queensland farmers have for many years shown a preference for high sucrose varieties and few countries grow varieties with the high sugar content of many of the Queensland varieties. In recent years N.Co. 310 developed in South Africa from Indian fuzz has set a high early sugar content comparable to or better than the best Queensland varieties ; in North Queensland, however, its free flowering habit renders it of little value for late harvest. Recently two C.P. varieties, C.P. 48-103 and C.P. 44-155, have shown a high sugar content in Queensland although these varieties are not of a type likely to become popular here whilst the Indian variety Co. 475 has demonstrated in North Queensland that it is capable of both a heavy yield and a high sugar content. Other overseas varieties introduced to date mostly show a lower sugar content than varieties developed in Queensland and it is certain that varieties only produce their highest sugar content under certain environmental conditions or as a corollary, different varieties require different environmental conditions to develop the highest sugar content of which they are capable.

PERCENTAGE OF HIGH SUGAR VARIETIES

In view of this fact and that the varietal requirements of Queensland are rather different from those of most other cane growing countries, as stated earlier, crosses which are successful for the production of high sugar varieties in Queensland may be useless for the development of commercial varieties elsewhere. Nevertheless at least some varieties which feature commonly in Queensland high sugar combinations might be useful as parents in other countries. In order to evaluate these parents, which consistently feature in the production of high sugar progeny, a list was made of all crosses which have produced varieties having a high sugar content in yield-observation trials at the Northern Sugar Experiment Station over the past five years. To compile the list only those varieties were selected which show a higher sugar content than the standard which was in each instance either Q.13, Pindar or Trojan. These three varieties all have a high sugar content and the first two have high early sugar. In the five years series of seedlings under review there were 149 varieties representing 67 families in yield-observation trials and these families were the result of the union of 29 females with 32 males in various combinations.

In Table I are listed separately the parentages of those varieties which produced high early sugar and high late sugar respectively. If a variety produced high sugar both early and late in the season its parentage is included in both categories. The figure in brackets following a cross indicates the number of varieties of that parentage which have a high sugar content.

TABLE I

High Early Sugar			
Badila	x	Comus	(1)
,,	x	Q. 27	(2)
G. 362	x	Q. 27	(3)
I. 209	x	Badila	(2)
Oramboo	x	C. 279	(1)
P.O.J. 2875	x	Q. 39	(1)
Pompey	x	Q. 39	(1)
Q. 13	x	Badila	(1)
Q. 27	x	Badila	(1)
,,	x	Comus	(1)
,,	x	G. 362	(1)
,,	x	Q. 31	(1)
Q. 44	x	Comus	(2)
,,	x	Oramboo	(1)
,,	x	P.O.J. 2940	(2)
S.J. 4	x	A. 285	(1)
Trojan	x	Q. 31	(1)
,,	x	Q. 39	(1)

High Late Sugar			
Badial	x	F. 363	(1)
,,	x	Q. 27	(2)
D. 285	x	Comus	(3)
G. 263	x	M 1900 Sdg.	(2)
G. 323	x	Badila	(2)
G. 362	x	,,	(2)
,,	x	Q. 27	(3)
H. 265	x	Q. 33	(1)
H.Q. 426	x	Q. 27	(1)
I. 209	x	Badila	(1)
Oramboo	x	Co. 290	(1)
Pompey	x	Q. 39	(1)
Q. 10	x	Q. 27	(1)
Q. 13	x	Badila	(1)
,,	x	Eros	(1)
Q. 13	x	G. 269	(4)
Q. 27	x	Badila	(2)
,,	x	Eros	(1)
,,	x	G. 269	(4)
Q. 44	x	Comus	(1)
,,	x	P.O.J. 2940	(2)
S.J. 4	x	A. 285	(1)
Trojan	x	Eros	(1)
,,	x	Q. 31	(3)
,,	x	Q. 39	(5)
,,	x	Comus	(1)
,,	x	Q. 27	(1)

There is not much indication from this Table that any particular cross was especially effective in producing commercial types with high early sugar except possibly G.362 x Q.27. The frequency with which Q.27 appears as a female (four times) and as a male (five times) indicates that it probably carries high early sugar with it whether used as male or female. This is fully in accordance with our experience of Q.27 as a parent for nearly 20 years. Following Q.27 the best results for early sugar appear to have been obtained using Q. 44 as a female (5 times), Badila as a male (4 times) and Comus as a male (4 times).

As far as high late sugar varieties are concerned, three crosses gave good results, Trojan x Q. 39 (5 times), Q.13 x G.269 (4 times), and Q.27 x G.269 (4 times) whilst D.285 x Comus, G.362 x Q.27 and Torjan x Q.31 (each represented 3 times) also showed some promise. The most successful females for high late sugar were Trojan (11 times), Q.27 (7 times), Q.13 (6 times), and G.362 (5 times) whilst the most successful males were Badila (8 times), Q.27 (8 times), G.269 (8 times), Q.39 (6 times) and G.362 (5 times).

The figures only indicate trends as they are considerably influenced by several factors. The number of progeny represented in the original planting of each cross varies greatly since some crosses germinate poorly ; consequently even though the selection rate in a particular cross is high more seedlings from a cross with a lower selection rate may reach yield-observation trials because there is a much larger initial progeny from which to select. Undoubtedly the figures are loaded in favour of varieties such as Q.13, Q. 27 and Trojan because they produce the erect type of variety so favoured by North Queensland growers; furthermore they all set seed freely. At the same time the figures do indicate that the parents which show up as producers of high sugar can produce seedlings with a high sugar content and, since they have reached yield-observation trials, with the necessary agricultural characteristics for commercial varieties.

Since it will no doubt be of interest to other cane breeders, Table II shows the parentage of all the varieties represented in Table I.

TABLE II

Variety	Parentage
A. 285	Korpi x Q. 30 (Black Cheribon x 28 N. G. 251)
Badila	New Guinea noble
C. 279	Badila x 21 N.G. 251
Co. 290	Co. 221 x D. 74
Comus	Oramboo x Q. 813
D. 209	J.B. 9 (P.O.J. 2878 x Q. 30) x Q. 31
D. 285	P.O.J. 2878 x Badila
Eros	P.O.J. 2878 x 31 M.Q. 228 (Badila x 27 M.Q. 1122)
F. 363	Korpi x C. 279
G. 263	Korpi x C. 279
G. 269	Korpi x C. 279
G. 323	Q. 13 x C. 278 (Badila x 28 N.G. 251)
G. 362	Q. 13 x K. 5 (S.J. 4 x Q. 30)
Goru	New Guinea noble
H. 265	Trojan x Q. 31
H.Q. 426	Goru x ?
I. 209	H.Q. 426 x C. 278
M. 1900 Seedling	Noble
Oramboo	New Guinea noble
P.O.J. 2875	P.O.J. 2364 x E.K. 28
P.O.J. 2940	P.O.J. 2722 x E.K. 28
Pompey	Petite Senneville x Malaia
Q. 10	Probably Korpi x H.Q. 409
Q. 13	,, ,, ,,
Q. 27	Unknown
Q. 31	Oramboo x H.Q. 409
Q. 33	Badila x S.C. 12/4
Q. 39	P.O.J. 2878 x Badila
Q. 44	Unknown
S.J. 4	Badila x ?
Trojan	Co. 270 x 27 M.Q. 1124 (Korpi self)

From a study of the parentage of these varieties some interesting facts emerge. Firstly, one of the best performers as a male, G. 269, is a second nobilisation of *robustum.* In fact no less than five of the parents which featured in producing high sugar varieties are second nobilisations of *robustum* whilst one, C.279, is a first nobilisation. This effectively disposes of the idea held in some quarters that *robustum* blood induces a low sugar content. Secondly, the continual occurrence of Korpi blood which, assuming Q.13 is a descendant of Korpi, as it almost certainly is, occurs in four of the most prolific high sugar parents, G.269, G.362, Q.13 and Trojan. The value of Korpi as a high sugar parent has been previously referred to by Buzacott (1, 2,) and Gard (3). Thirdly, whilst there is a predominance of noble blood and a fair sprinkling of *robustum* blood there is little *spontaneum* blood represented when one considers the number of parents originally having *spontaneum* blood. This fact probably highlights not the difficulty in producing high sugar in varieties with *spontaneum* blood so much as the difficulty of obtaining suitable types of cane for North Queensland conditions when *spontaneum* blood is incorporated. From the point of view of tillering alone a percentage of *spontaneum* blood is most desirable and that good varieties for North Queensland can be produced with *spontaneum* blood is emphasised by the great success in the tropics of Pindar and Trojan both of which were developed by the Colonial Sugar Refining Company from Co. 270. It is interesting to note that although many of the varieties which figure in the parentage of high sugar varieties have high sugar themselves such as H.Q. 426, Q.10, Q.13, Trojan etc., in some instances it does not always follow. A notable example is found in the cross G.362 x Q.27. These are both varieties which just failed to become commercial varieties because their sugar content was slightly below that of commercial standards in Queensland.

METHODS TO ENSURE HIGH SUGAR SELECTIONS

Many attempts have been made to try and put the breeding of high sugar varieties on an orderly basis, but there still seems to be no predictability about it. Loh and Tseng (5) have indicated that the transmission of high sucrose is sex linked with the female. This may or may not be so but there is strong evidence in Queensland that some varieties such as Korpi and Q.27 can transmit high sugar whether used as male or female.

In our experience the only sure method of ensuring high sugar varieties is to make crosses which produce a reasonable percentage of high sugar varieties. Admittedly, this may not be theoretically sound since the greater the variability of the sugar content of the progeny the more likely a really outstanding sugar content will be obtained. However, in practice the use of great variability is usually restricted by the large populations which it becomes necessary to handle, since not only has the exceptional sugar content to be achieved but also this has to be combined with other good agricultural characters. Therefore, unless crosses are chosen which produce a reasonable percentage of high sugar seedlings, the likelihood of selecting any suitable commercial types is very remote unless huge populations are handled. For this reason, apart from the consideration that environmental influences reflect on the value of brix values in the selection of original seedlings, brixing them can be a very useful aid in determining the value of new crosses. This applies only to space-planted seedlings. The brixing of bunch-planted seedlings in the original planting would probably have little value because of the intense competition acting on each individual stalk. On the other hand, the general remarks regarding the necessity for planting crosses which produce a reasonable percentage of high sugar seedlings still applies to bunch-planting because, with no elimination on brix in the original selection, the use of low sugar combinations in bunch-planting would soon result in 5 x 3 selection plots becoming littered up with low sugar varieties. With the enormous amount of parental material now available, most countries are carrying out a large number of new trial marriages each year and it is desirable to evaluate as rapidly as possible the potentialities of any cross to produce seedlings with a high sugar content.

Arising out of this information two courses appear obvious, firstly to make biparental crosses between all females and males which have a good record; secondly to use in a polycross the female parents which have a good record with all the males which likewise have performed well. One objection to the latter method is the possibility that one male may effect most of the fertilization. The ease with which certain males, in particular certain *robustum* varieties can effect fertilization even where it is not desired seems to indicate the ability of some males to fertilize ahead of others and this tendency might affect the value of a polycross as a method of testing the reaction of female parents to multiple males.

It is necessary to explain that the remarks made above refer to breeding for North Queensland and essentially tropical conditions. Few of the crosses detailed could be successful agriculturally in central or southern Queensland where the success of *spontaneum* types has been amply demonstrated. However the problem of high sugar is still a pressing one for certain North Queensland areas and the necessity for temporary restriction in sugar output gives less vigorous but higher sugar content canes an opportunity of being fully tested. The desire of most farmers to produce the greatest tonnage of cane possible during the recent expansion programme in the Queensland industry led many of them, at least temporarily, to prefer vigour to high sugar.

SUMMARY

Owing to dissimilar climatic conditions and other requirements of a commercial variety due to different methods of harvesting and cultivation it would seem that each country must work out its own combination of parents to produce high sugar commercial varieties. Experience in Queensland indicates there is no substitute for progeny testing in order to determine the best parent

varieties to use. A rough analysis is given of the relative value of parents of high sugar varieties which have reached yield-observation trials over a period of five years at the Northern Sugar Experiment Station. A review of this analysis suggests that at least under tropical Queensland conditions, the use of certain varieties will give a greater chance of producing seedlings with a high sugar content and also with the agricultural characters necessary for North Queensland. Since the types considered are those selected for essentially tropical conditions the information may be of value to cane breeders in other tropical areas.

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Dr. A.J. Mangelsdorf then presented his paper.

Paper

SUGAR CANE BREEDING : IN RETROSPECT AND IN PROSPECT*

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The cane sugar industry rightfully looks to its technologists for help in safeguarding its competitive position. Its chemists, engineers, agronomists, physiologists, entomologists, pathologists and geneticists all share in this responsibility, and all have contributed to the remarkable progress that has been realized in recent years. The amount of labour expended in producing a ton of sugar today is a mere fraction of what was required fifty or even twenty-five years ago.

Quite naturally, we take pride in the vigorous, disease-resistant hybrids which the sugarcane breeders have contributed from time to time and which have helped to save one region after another from the brink of economic disaster. In our enthusiasm over the progress that has been achieved by our own generation, we are prone to forget the contributions of our prehistoric predecessors who succeeded in developing from useless wild grasses with fibrous, low sucrose stalks, the remarkable varieties which we have inherited from them. Prominent among these old varieties are those known in one country or another as Vellai, Otaheite, Cana Blanca, Lahaina or Bourbon,—as Tanna, Malabar or Caledonia,—as Preanger, Cristalina or Rose Bamboo,—as New Guinea 15 or Badila. These original varieties of prehistoric origin have served our industry both as commercial canes and as breeding material.

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*Certain passages in this paper have been excerpted from earlier papers (1,2,3). Numbers in parentheses refer to literature citations.

Nothing is known with certainty as to the origin or antiquity of these so-called "native" varieties. We only know that sugarcane has been cultivated by man since prehistoric times. We may conclude from the fact that no *Saccharums* with juicy, high sucrose stalks have yet been found perpetuating themselves in the wild, that the old *officinarum* varieties owe their development and survival to human intervention.

SUCROSE GENES

With few exceptions, the stalks of the wild *Saccharums* contain but little sucrose. In these wild forms, the surplus products of photosynthesis are for the most part elaborated into fiber—a complex of cellulose, pentosans and lignin—which is laid down in the building of new tissue in the elongating stalks.

The genes that impair the elaboration of fiber, and thus promote the accumulation of sucrose in the stalks of the cultivated varieties, may be thought of as defective mutant alleles of the original normal or wild-type genes. While indeed defective from the standpoint of the normal physiology of the wild species, these aberrant genes have made possible the transformation of a worthless grass into a rich source of human food.

In the closely-related diploid genus *Sorghum*, it has been shown that the two contrasting types, one high in fiber and low in sucrose, the other low in fiber and high in sucrose, are differentiated by the action of alternative alleles at a single major locus. (Both types may be affected to a minor degree by modifying genes). In the highly polyploid genus *Saccharum* it appears that more than one locus is involved in determining differences in the fiber-sucrose ratio, but the evidence indicates that the number of genes involved is not large.

Gene mutations which impede the elaboration of fiber and lead to an accumulation of sucrose have apparently arisen independently in *S. robustum*, to give rise to ancestors of the noble canes, and in *S. spontaneum*, occasional clones of which are reported to contain appreciable amounts of sucrose.

SHORTCOMINGS OF THE NATIVE VARIETIES

In the Indonesian and New Guinea regions, sugarcane was domesticated by man for direct consumption rather than for the manufacture of sugar. The native varieties of these regions are admirably suited for eating out of hand.

In India the art of making sugar from sugarcane is an ancient one. Only within the last two centuries however, has cane sugar production been transformed from a cottage industry to a large scale plantation activity.

This change brought with it a change in the specifications to which a satisfactory variety must conform. Because of their soft rind, the stalks of the native chewing canes are vulnerable to fracturing and to attack by pests of various kinds. With the advent of steel rollers operating under high pressures and driven by steam power, extreme softness ceased to be an asset. Moreover, the old "noble" varieties as a group lacked resistance to several serious diseases. Diseases which were of little importance in backyard plantings spread to epidemic proportions when extensive areas were planted to a susceptible clone.

BEGINNING OF MODERN SUGARCANE BREEDING

The early botanists who first examined sugarcane flowers found no evidence of seed formation ; they concluded that long-continued asexual propagation had caused sugarcane to lose its capacity for seed production.

The belief that sugarcane was sexually sterile was not entirely unfounded. Among the thousands of spikelets in a tassel of Yellow Caledonia, only an occasional one is functional. Many of the so-called "native" Hawaiian canes have in common a tassel of characteristic shape and colour, the stigmas and anthers of which are abortive. Although the individual varieties in this group of more than twenty native Hawaiian canes differ among each other in stalk colour, in leaf colour and in leaf shape, their peculiar tassel leads us to suspect that they may represent sub-clones of a single original clone, the somatic mutants of which were preserved by the Hawaiians and given variety names.

The "Transactions" of the Royal Hawaiian Agricultural Society record that at its first meeting, held in Honolulu on August 14, 1851: "The Society met at half past nine, the President in the chair...On motion of Mr. Marshall,—Resolved. That a committee be appointed to institute experiments with a view to obtaining plants from the seed of sugar cane, and to procure information on this subject." The failure of this pioneer effort is understandable in view of the prevalence of sterility among the native Hawaiian canes.

In 1858, J.W. Parris, a planter in Barbados, succeeded in growing to maturity some sugar cane seedlings which appeared as volunteers in one of his fields. A local newspaper, the Barbados Liberal, in 1859 published Mr. Parris' account of his experience. However, the seedlings proved to be inferior to the varieties already being grown, and the achievement was soon forgotten.

The renaissance of sugar cane breeding may be credited to the "sereh" disease epidemic which in the 1880's threatened the survival of the Java sugar industry. The desperate straits of the industry led Soltwedel, a Dutch botanist working in Java, to re-examine the question of the sexual fertility of sugar cane. In 1885, Soltwedel began a study of the reproductive organs of representatives of the genus *Saccharum*. He soon found that the pollen of *S. spontaneum* was normal in appearance. He subsequently ascertained that this pollen was capable of fertilizing flowers of the same species and that flowers thus fertilized produced viable seed. In 1887, he succeeded in germinating and growing to maturity seedlings from tassels of a "noble" cane (*S. officinarum*) of a variety known in Java at that time as "Yellow Hawaiian."

Soltwedel's findings disposed of the time-honored belief that all sugar canes were sexually sterile. Soltwedel thus provided the basis for a new beginning in sugar cane breeding.

In January 1888, volunteer sugar cane seedlings were again observed in Barbados, this time by J. B. Pilgrim, an overseer at Dodds. He brought these volunteers to the attention of J.B. Harrison, the Colonial analytical chemist and John Bovell, the manager of Dodds, who transplanted some sixty of these seedlings for further observation. In January 1889, Harrison and Bovell obtained germinations from field-collected tassels, the "fuzz" of which they had sown in boxes. The programme of seedling propagation thus initiated in Barbados is now in its sixty eighth year.

In the course of time other countries followed the lead of Java and Barbados and embarked upon breeding programmes of their own. Hawaii was somewhat tardy in this respect; its first population of five thousand seedlings was germinated in 1905.

INTER-REGIONAL EXCHANGE OF BREEDING MATERIAL

The history of sugar cane breeding affords many examples of fruitful cooperation in exchanging breeding material. In 1890, Java obtained from India the native Indian variety Chunnee. This variety proved resistant to the sereh disease which was causing serious losses in Java. The Proefstation Oost Java at Pasoeroean crossed Chunnee with Black Cheribon, which at that time was the major variety of Java. From this cross they obtained the hybrid P.O.J. 213 along with a number of others.

Some years later the Coimbatore Station explored the potentialities of P.O.J. 213 as a breeding cane. Its usefulness in India may be judged from the frequency with which it appears as an ancestor in the pedigrees of Coimbatore varieties.

All of the present major varieties of Hawaii include in their ancestry 32-8560, itself until recently the leading variety in the Territory. The mother of 32-8560 is the Indian variety Co. 213, a seedling of P.O.J. 213. The father of 32-8560 is the Java variety P.O.J. 2878.

The pedigrees of the commercial varieties of other countries provide similar evidence of the importance of inter-regional exchange of breeding material. The progress that has been achieved in sugar cane breeding during the past sixty years reflects the contributions of genes from many diverse strains of *Saccharum* and the efforts of breeders in many countries.

In many regions, modern varieties of hybrid origin are displacing the old native varieties, some of which may be irretrievably lost unless prompt measures are taken to assemble and safeguard them for future use in breeding.

The once-extensive breeding collection of the Proefstation Oost Java has suffered from war-time and post-war disruptions. The fate of the Java collection is still uncertain. Fortunately some of the items in this collection are duplicated in the U.S. Department of Agriculture collection at Canal Point, Florida. Through its Sugar Crops Section, the USDA has for many years fostered the collecting of sugar cane germplasm. Even this extensive collection is still far from complete.

The sustained interest of the Coimbatore Sugarcane Breeding Institute and the Government of India in assembling and safeguarding the world's resources of sugar cane germplasm has been evidenced by their various collecting expeditions and most recently by their decision to undertake the maintenance of a second World Collection of Sugarcanes. These activities are deserving of the gratitude and support of the entire world's cane sugar industry.

UTILIZATION OF WILD CANES IN BREEDING

Since the breeder is as yet unable to create at will genes that are capable of conferring the traits which he requires, he is obliged to content himself with synthesising new combinations of the genes available in whatever breeding material he has been able to assemble. While the old noble varieties are remarkable in many respects, they are deficient in disease resistance and in hardiness. Fortunately, the wild and primitive relatives of sugar cane are proving a good source of genes by means of which the deficiencies of the noble canes can be corrected.

Breeding experience during the past half century has shown that genes capable of contributing to higher yields are widely dispersed among the many strains of the genus *Saccharum* and possibly also among the members of related genera. Such improvement as has been realized through breeding has been achieved by bringing together in a single individual the desirable traits of a wide diversity of parent strains, while excluding, in so far as possible, the shortcomings of these parent strains. This has involved a step by step, generation by generation synthesis, with an indispensable interval between generations for selection and testing to provide reasonable assurance that ground was being gained rather than lost.

The first attempt at utilizing wild relatives of sugar cane as a source of disease resistance was made in Java in 1893, when Wakker crossed Black Cheribon with Kassoer. Black Cheribon, an *officinarum* cane, was at that time the leading variety of the Java sugar industry. Kassoer, a wild cane subsequently shown by Bremer to be a natural hybrid of *S. officinarum* and *S. spontaneum*, possessed a high degree of resistance to the sereh disease to which Black Cheribon was highly susceptible. This line of attack led eventually to the synthesis of the variety P.O.J. 2878 which proved highly resistant to sereh disease and which in time became the leading commercial variety in Java and in many other countries.

A similar line of attack has been employed in the Indian breeding programme since its very beginning. The Coimbatore varieties undoubtedly owe much of their success to the vigour and disease resistance contributed by the *spontaneum* and the other hardy Indian canes in their ancestry.

In Hawaii, the complex hybrids of Java and India have been crossed to bring together in a single variety the desirable qualities of *S. officinarum*, *S. barberi* and *S. spontaneum*. Subsequent hybridization has added genes of the wild *S. robustum* of New Guinea. The present leading variety in Hawaii, 37-1933, has in its ancestry representatives of both the *officinarum* and *Barberi* groups of cultivated varieties and both *spontaneum* and *robustum* groups of wild *Saccharum*.

BREEDING STRATEGY

The response of sugar cane to inbreeding and out-crossing is similar to that of maize. The sugar cane flower is normally provided with both male and female organs, but male sterility is frequently encountered. Among the varieties that produce an abundance of pollen, some are fully self-fertile, but many are partially or highly self sterile. Protogyny also occurs in varying degrees. When sugar cane is subjected to self-pollination, the usual result is a reduction in seed setting and a marked depression in the vigour of the offspring. As in maize, crossing between inbred lines whose vigour has been impaired by inbreeding usually results in vigorous offspring. Exceptions to this rule may be encountered in crosses between inbred lines that are closely related.

Breeding strategy in Hawaii seeks to exploit the opportunities and advantages inherent in a crop which is naturally cross-fertilized, highly heterozygous, and asexually propagated , and which manifests the characteristic decline in vigour upon selfing and the restoration of vigour upon outcrossing commonly found among other naturally cross-fertilized organisms.

This strategy is not static ; it has changed in the past, and it will no doubt continue to change in the future as new information becomes available. Although its status has been examined in detail in recent papers (2, 3, 4, 5, 6), certain aspects will again be reviewed in order to bring them before this meeting for consideration.

INHERITANCE AND EVALUATION OF YIELD GENES

Components of sugar yield are, (a) tons of cane per unit of time and area and, (b) percentage of recoverable sugar in cane. Any gene that impinges upon any of the physiological processes of the cane plant in such a way as to affect one or both of these components may be classed as a yield gene.

A particular yield gene may be effective under one environment, and not in another. Thus a gene that determines only resistance to a specific disease may exert a large effect upon yield in the presence of that disease, and none in its absence. Similarly, a gene for drought resistance may result in a large increase under droughty conditions, while having no effect in a situation where soil moisture never declines to the wilting point.

In view of the complexity of the interactions of yield genes with each other, and with the environment, which is itself subject to diurnal, seasonal, annual, and random fluctuations, and in view of the difficulties that stand in the way of measuring the effect of a particular yield gene, it is not surprising that there should be a dearth of factual evidence regarding the identity and mode of action of individual yield genes.

In this respect the position of the sugarcane breeder is neither better nor worse than that of breeders working with other crops or with livestock. The maize plant, for example, has received the attention of scores of geneticists who have mapped for its ten pairs of chromosomes the positions of hundreds of genes that determine visible traits. In spite of this wealth of genetic information, the identity of the genes responsible for the differences between a high-yielding and a low-yielding commercial maize hybrid remains unknown.

Both physiology and physiological genetics are still in their infancy. Each advance reveals new areas of ignorance. What has been accomplished provides a mere inkling of how much remains to be discovered regarding the intricacies of the physiological processes of living organisms.

These facts are not to be interpreted as leading toward a counsel of despair. The evidence to date suggests that each step in each physiological process is gene-conditioned, if not gene-determined. The belief that yield genes are transmitted from parents to offspring by the same mechanism, and according to the same rules that govern the genetic transmission of visible traits, is supported by evidence from many sources.

The inability of the breeder to identify the individual yield genes need not preclude his exploitation of these genes in breeding towards higher yield. The breeder deals with the yield genes as he deals with genes that determine visible traits. He makes crosses between selected parents, and he relies upon segregation and recombination to provide in subsequent generations variation among the descendants, which in turn, provides opportunity for the selection of individuals that surpass their parents in their approximation of the desired goal.

Likewise, in planning his testing procedures the sugarcane breeder takes cognizance of the limitations of existing knowledge as to the effects of environmental differences upon photosynthesis and upon the other physiological processes which determine yield. He endeavours to subject his populations to the environmental conditions under which the future commercial variety is to be grown in order to permit the individual seedling to act as the integrator of the favourable and unfavourable genes which it has received from its parents. The fact that a particular genotype may yield well in one environment and poorly in another emphasizes the need for localized testing. If the region served by the breeding programme embraces several distinct ecological zones, testing must be carried on in each of these several zones. In Hawaii this requirement has led to the establishment of nine regional variety testing stations so distributed as to bracket the major ecological zones of the Islands.

SELFING VERSUS PROGRESSIVE SYNTHESIS

The possibilities of selfing to provide superior breeding canes for use in subsequent crossing have been under investigation in Hawaii since 1926. The spectacular success of the selfing approach in the production of hybrid maize helped to fuel the interest in this line of attack.

The revolution in maize breeding which began more than thirty years ago was based upon the finding that inbred lines, although themselves lacking in vigour, when crossed in certain combinations were able to produce vigorous, uniform, high yielding progeny. The uniformity of the hybrid offspring stems from the fact that repeated selfing or sibbing had rendered the inbred parents homozygous, or nearly so. Once the maize breeder has found a happy combination between two of his inbred lines, he can reproduce this cross in quantity.

In addition to its inbreeding-crossing programme, this Station has also pursued a programme of progressive synthesis which has as its objective the concentrating of desirable traits originally dispersed among the many and diverse parent varieties in the breeding collection. This programme calls for recurring cycles of crossing and selection, without the interposing of one or more generations of selfing between crossing cycles.

Under the latter programme, Co. 213 was crossed in 1932 with P.O.J. 2878 to produce 32-8560, which eventually became the leading variety in Hawaii. In 1932 also, P.O.J. 2878 was crossed with the Port Moresby *robustum* to produce 32-6774. In 1934, 32-6774 was crossed with 27-8101 to produce 34-1874. This cross brought together genes of P.O.J. 2878 and Port Moresby *robustum* from the male side, and genes of Yellow Caledonia, H. 109 and Badila from the female side. In 1937, 32-8560 was crossed with 34-1874 to produce 37-1933, which in due course succeeded its mother as the leading variety.

During the early years of the selfing project, the reasoning in support of this procedure was based upon the certain knowledge that segregation and recombination must result in a range of genotypes in the selfed population, some of which would be inferior and others superior (in respect of combining ability in certain crosses) to the heterozygous parent from which they were derived. It was hoped that phenotypic selection among the selfs might prove an effective means of identifying superior breeding canes. This hope has not been realized.

An example will serve to illustrate the disadvantages under which the selfing—crossing programme operates. As the desirable qualities of 37-1933 began to become evident it was used as a parent in as many crosses as the limited supply of tassels would permit. In subsequent years, 37-1933 was also selfed on an extensive scale. Although producing an abundance of pollen, it proved to be rather highly self-sterile—a common trait in sugar cane. Nevertheless by selfing a large number of tassels, it was possible to grow some hundreds of selfs of 37-1933. Those which appeared to have inherited a preponderance of desirable qualities and a minimum of faults were retained for use in breeding in the hope that an occasional individual might prove outstanding as a parent.

As tassels became available in increasing number, 37-1933 was used more and more extensively in crosses. In 1943, the crosses in which 37-1933 served as one parent produced 451 seedlings. In subsequent years the following numbers of seedlings of 37-1933 were grown; 1944—2050 ; 1945—12,452 ; 1946—16,460 ; 1947—14,150 ; 1948-—47,461 ; 1949—47,075 ; 1950—47,351.

By 1950, some 200,000 seedlings of 37-1933 had been grown. As certain of these seedlings began to show evidence of superiority over their 37-1933 parent in one respect or another, they were used in further crossing. Breeding interest began to shift from 37-1933 to its seedlings.

Meanwhile, the selfs of 37-1933 are still being tested for breeding behaviour. Theoretical considerations suggest that some will prove superior to their parent in certain combinations, and not in others. Those combinations in which both the self and its mate happen to be afflicted with the same physiological bottlenecks would hardly be likely to produce superior progeny.

An adequate evaluation of the breeding potentialities of each of the forty selfs of 37-1933 which still remain in the breeding collection would be a major undertaking. The outcome of one or even of several test crosses might or might not provide a fair indication of what might be expected when that particular self is used as a parent in still other combinations.

Although these selfs have been and are being subjected to test crossing as opportunity permits, it is not yet possible to point to any one of them as being a superior parent. Meanwhile the breeding programme has advanced by another gener tion ; interest now centers, not in 37-1933, but in some of its seedlings.

Since budget limitations permit the execution of only a fraction of the many crosses that we should like to explore, we are obliged to confine ourselves to those lines which appear most promising. The expenditure of further breeding effort upon 37-1933 or upon selfs of 37-1933 must be regarded as a doubtful investment in view of the opportunities to be explored at the more advanced stages of the progressive synthesis programme. Certain seedlings derived from crosses between 37-1933 and 39-7028, for example, are believed to offer more promise as parents than do the 37-1933 selfs.

The case of 37-1933 is cited as typical of the disadvantages of a selfing programme when in competition with a programme of progressive synthesis.

To recapitulate, the failure of the selfing-crossing project to measure up to expectations may be attributed to the following considerations :

(a) The uniformity which characterizes the progeny of a cross between two inbred lines and which confers such a great advantage in the breeding of seed-propagated crops is a disadvantage in the breeding of crops that can be propagated asexually. A single outstanding individual has no immediate value in the breeding of seed-propagated crops such as maize, where a superior population must be the objective. In the breeding of crops that can be propagated asexually, the superior individual, not the population, becomes the unit of selection. Obviously the chances for the occurrence of an exceptionally outstanding individual are greater in populations having high genetic variances than in populations having equally high means but low genetic variances. An inevitable consequence of inbreeding, whether by selfing or by sibbing, is a reduction in the genetic variance of the progeny of the inbred parents.

(b) Selfing results in a decline in vigour and in increased frequency of sterility. Inbreds when used as female parents in crossses produce, on the average, fewer seedlings per tassel than do heterozygous parents. This leads to an increase in per seedling costs.

(c) The loss of vigour which accompanies inbreeding is inimical to tasseling. If tassels can be had only from the heavier tasselers among the inbred parents, the inevitable result will be a trend among their progeny toward heavier tasseling. In Hawaii with its two-year cropping, freedom from tasseling is a major objective in the breeding programme.

(d) The selfing-crossing approach is costly in terms of time. The interposing of one or more generations of selfing between each generation of crossing doubles or more than doubles the number of years required to bring together in a single individual the desirable traits of four grandparents or of eight great-grand parents.

(e) The breeding potentialities of a selfed line cannot be predicted from its appearance. Only by subjecting the self to test crossing is it possible to determine its value in breeding. The goodness of its progeny from one combination may or may not provide an indication of its breeding value in other combinations.

Among the theoretical considerations which cast doubt upon the soundness of interposing one or more generations of selfing between each generation of crossing are the following. The processes of segregation and recombination upon which the breeder must rely for new combinations of genes are effective only at heterozygous loci. On the average, each generation of selfing converts half of the heterozygous loci to the homozygous condition. Unfortunately, both desirable and undesirable genes are rendered homozygous at the same rate.

In the past, considerable effort has been devoted to searching for "nicking" combinations—crosses that produce higher than average proportions of selectable seedlings. Once such a superior combination has been identified, the cross has then been repeated on a large scale, sometimes year after year, in order to exploit its possibilities to the fullest. The hope that selfing will provide a means of developing such superior combinations which, once identified, could then be repeated on an extensive scale, as is done with maize, fails to reckon with the fact that the F_1 population from a cross between two homozygotes has a genetic variance of zero. Since a cross between two homozygotes can produce but a single genotype, which in sugar cane can be multiplied asexually, the breeder would have no reason to grow more than a single seedling from each such cross.

The progressive synthesis programme employs a basically different approach. It emphasizes the prompt utilization of the superior new seedlings themselves as parents in further breeding, rather than the large-scale repetition of the crosses which produced those seedlings.

There are sound reasons for keeping to a minimum time interval between successive cycles of crossing and selection. At a given effectiveness of selection the amount of progress that can be realized in shifting gene frequencies in the desired direction is determined by the number of generations of crossing and selection that can be accomplished within a given period of time.

If each of two independent and desirable traits have a frequency in the population of one in a thousand, only one individual in a million will possess both traits. To provide a reasonable chance of finding in a single generation an individual endowed with, say, five desired traits, each inherited independently of the other four and each of low frequency in the population, an astronomically large population would have to be grown and examined.

The breeder cannot grow and examine populations of astronomic size ; he must content himself with populations of manageable size. Moreover, he knows that populations of thousands carried through successive generations of crossing and selection directed toward the desired goal will be more likely to give him what he is looking for than would populations of millions in any single generation. Since generation-by-generation selection pressure provides his only effective substitute for large numbers, he makes every effort to achieve within a given period of time as many generations as can be had without too great a sacrifice in effectiveness of selection. It is understandable that he should view with distrust any diversion that might threaten to militate against his full utilization of this tried and proven procedure.

It is of interest to note that, although selfs appear in the pedigrees of several of the world's commercial varieties, the majority have come from crosses between heterozygous parents. This in itself can provide no conclusive evidence as to the relative merits of the two contrasting lines of attack. However, both theoretical considerations and breeding results lead us to believe that the objective of rapid progress can best be served by ;

(a) exploiting the high genetic variance which characterizes the progeny of crosses between heterozygous parents, and

(b) devoting the available resources to recurring cycles of crossing and selection in a programme of progressive synthesis aimed at concentrating in a single individual the desired traits of many ancestors, while excluding, so far as possible, the weaknesses of these ancestors. In our experience the expenditure of years and money to interpose one or more generations of selfing between each cycle of crossing has proved unprofitable.

MELTING POT CROSSING AND BUNCH PLANTING

In Hawaii, several techniques have been developed to deal with the limitations imposed by high labour costs and by the briefness of the crossing season. Foremost among these are melting pot crossing (polycrossing) and bunch planting. These techniques have been described elsewhere (3, 5).

Melting pot crossing provides a wide diversity of combinations at low cost. Increasing use is being made of specialized melting pots as a means of producing seedlings for specific ecological conditions.

The bunch planting procedure provides a means whereby the large numbers of seedlings afforded by melting pot crossing can be accommodated in the field.

These two procedures, employed judiciously in conjunction with each other, enable the breeder to deal with larger populations from a greater diversity of combinations than could possibly be managed under the conventional bi-parental crossing and space planting procedures.

Bi-parental crossing will continue to play an indispensable role in effecting specific combinations of high priority. However, unless and until a positive means can be developed to induce tasseling at will, the breeding programme in Hawaii must continue to lean heavily upon melting pot crossing to ovide the desired diversity in its seedling populations.

TASSELING IN RELATION TO SUGARCANE BREEDIN

Day-length is known to be an important factor in determining whether and at what season the growing point of a sugarcane stalk will cease to produce leaf primordia and will differentiate into a tassel bud. In the Northern Hemisphere, the tasseling season begins near the Equator in September, gradually progressing northward, reaching 10° North latitude by October and 20° North latitude during November and December. In the Southern Hemisphere, we have a mirror image of this situation ; the tasseling season begins near the Equator in March and reaches 20° South latitude during May and June. Thus in both the Northern and Southern Hemispheres, the change from a growing point to a tassel bud occurs during the period of shortening days.

Early-tasseling varieties such as P.O.J. 2878 first show macroscopic indications of a tassel bud when the day-length, including twilight, has shortened to 12½ hours or thereabouts. At the latitude of Honolulu, this occurs in September. It is possible, of course, that the minute tassel bud may be several days old before it can be recognized as such, and further, that the conditions responsible for its development may have antedated its first visible appearance by some days, or perhaps even by weeks.

In Hawaii, 19° N to 22° N, most varieties of sugarcane come into flower during November and December. There are, however, some exceptions to this rule. An occasional tassel of 32-8560 can be found in certain upland districts even during the summer months. The primitive form of *S. spontaneum*, collected by Dr. E. W. Brandes in Turkestan (40° N), requires a long day for tassel differentiation. At the latitude of Washington, D.C., it flowers in August. When grown near the Equator, it fails to tassel, presumably because the perpetual twelve-hour day at the Equator is too short to induce tassel differentiation in this variety.

A variety of *S. spontaneum* which grows wild near Tokyo behaves in a similar manner. In its natural habitat, it flowers in late summer. When carried to Formosa, which lies a thousand miles nearer the Equator, it refuses to flower. The maximum summer day-length in Formosa is about fourteen hours. For tassel differentiation, the Tokyo form of *S. spontaneum* apparently requires a day-length greater than fourteen hours.

In Hawaii, attempts to induce these long-day forms to flower by supplementing the natural day-length with artificial illumination have thus far met with no success.

It appears that each variety has a day-length range within which tassel differentiation is able to proceed and beyond which no differentiation occurs. Some varieties are precise and exacting in their day-length requirements for tasseling ; the tasseling season of such varieties is brief. Others are able to produce tassels over a wide range of day-lengths ; these are characterized by a long tasseling season. The tasseling time of the latter group may be somewhat controlled by age. However, the flowering date of most varieties is affected only slightly, if at all, by the date of planting. Later planting may greatly reduce the percentage of tasseling without delaying materially the time of tasseling.

Under the conditions of the Kailua breeding station, the time interval between the first macroscopic evidence of tassel differentiation and the emergence of the tassel from its "boot" ranges from 50 to 70 days. The length of this period is influenced by temperature and presumably by other conditions related to rate of growth.

While a suitable day-length or, more precisely, a suitable night-length, is the first pre-requisite for tassel development, tasseling may or may not ensue, even though the day-length requirements have been met. Other factors affecting tasseling are considered in the following paragraphs.

Physiological age. Stalks which are too young when the proper day-length for differentiation arrives, fail to tassel. The stage of maturity necessary for tasseling differs with different varieties. Stalks of P.O.J. 2725 which have only two or three mature internodes may tassel. On the other hand, stalks of B.H. 10/12 which have only a few mature internodes never produce tassels. Apparently the presence of a considerable number of mature internodes is pre-requisite to floral differentiation in many of the shy tasselers. Even with adequate stalk development the percentage of tasseling stalks in reluctant tasselers, such as B.H. 10/12, is low.

Drought. Tasseling may be prevented by drought even when all of the other requirements have been met. Tassel bud differentiation is unable to proceed if soil moisture throughout the root zone is held below the wilting point. If the drought is terminated early enough, tassel development may be merely delayed. However, an entire field of a heavy tasseling variety may escape tasseling if the drought persists well into the tasseling season.

Climate. Sugarcane tassels more freely under the cloudy, rainy conditions of the windward districts than under the sunny conditions of the leeward districts, even when the latter are supplied with an abundance of irrigation water. The reason for this difference is not clear. It may possibly be connected with (a) differences in the quality or quantity of sunlight reaching the cane plant or, (b) differences in minimum temperature or in the range between minimum and maximum temperatures.

The incidence of tasseling is also affected by elevation. The optimum elevation for tasseling is somewhat dependent upon latitude, near the Equator, some varieties of sugarcane are able to tassel at elevations above five thousand feet, while at the latitude of Hawaii, sugarcane rarely tassels at elevations above two thousand feet. This again may be associated with a minimum temperature threshold.

Other factors. The higher the soil fertility and the more rank and succulent the growth of the sugarcane plant, the less likely it is to tassel. Ratoon cane tassels more heavily than does plant cane. The heaviest tasseling usually occurs on eroded slopes and knolls. Erect stalks are more likely to tassel than are recumbent stalks. Tasseling is usually heavier along the edges than in the interior of the field. Whether this is due to a difference in solar radiation or to a difference in air soil temperature is not known.

NEED FOR MEANS OF CONTROLLING TASSELING

Both the breeder and the grower are concerned with tasseling. From the standpoint of sugar production, tasseling represents a dissipation of energy. It also marks the end of the terminal growing point. Since the lateral buds (lalas) which develop after tasseling are vulnerable to wind breakage they are at best a poor substitute for the terminal growing point. An economical means of preventing tasseling in heavy-tasseling varieties would be a boon. It would help the grower by reducing yield losses, and it would help the breeder by qualifying as commercial candidates seedlings which must otherwise be disqualified only because of excessive tasseling. A still better solution of the problem is provided by high-yielding non-tasseling varieties when such varieties are available.

Crosses between heavy-tasseling parents produce a preponderance of heavy-tasseling offspring. The sugarcane breeder is in need of a technique for inducing tasseling in the non-tasseling and light-tasseling varieties so that he can use these varieties in breeding toward freedom from tasseling. Moreover, the problem of synchronizing the flowering of early-and late-tasseling varieties to permit crosses between the two would also be solved if a positive means could be devised for inducing flowering.

The problem of crossing early and late-tasselers would also be solved if pollen of the early-tasselers could be kept alive and functional until the late tasselers begin to bloom. The viability of the pollen of certain fruit crops can be maintained for many months by storing at temperatures of 0° C or lower. Pollen of the *Gramineae*, however, is notoriously perishable ; it loses its viability rapidly under the storage treatments thus far explored.

The sugarcane breeder looks enviously at the procedures whereby the pineapple plant can be induced at will to develop flower buds. In the pineapple, appropriate applications of ethylene, acetylene, alpha-naphthalene acetic acid, and even 2, 4-D, result promptly in floral initiation. These treatments, and many others, have been tried on sugarcane, but thus far without success.

The many advantages to be gained from a successful solution of these problems afford ample justification for further research both on pollen storage and on tassel induction. Meanwhile, it is highly desirable that the breeding station be situated in an environment known to be conducive to abundant flowering. A breeding station which is poorly situated in this respect operates under a very great handicap, since many varieties are shy tasselers even under the most favourable conditions.

IN PROSPECT

A reliable crystal ball would afford the sugarcane breeder considerable aid and comfort. A portable model that he might carry into the field while making his selections would be particularly helpful.

Having at our command neither a crystal ball, nor any other means of divination, we can only speculate as to what the future may hold in the way of developments that will contribute to further progress in sugarcane breeding. As guesses, we hazard the following :

(a) Cane sugar producing areas not yet engaged in breeding will initiate breeding programmes. Exchange of information and breeding material among workers in sugarcane breeding will be intensified.

(b) New material from regions not yet adequately combed for breeding canes will be added to the world collections of sugarcane germplasm. The breeding potentialities of these collections will be more intensively exploited.

(c) New and valuable alleles will be contributed to the genetic complex by distant relatives of sugarcane, such as *Narenga*, *Imperata*, *Miscanthus*, *Erianthus*, *Sclerostachya* and others.

(d) Irradiation and other mutagenic agents will provide new and useful mutations.

(e) Cytogenetic studies of sugarcane will lead to a better understanding of the details of its genetic mechanism.

(f) Improvements in crossing technique will result in more efficient utilization of the tassels available during the crossing season. A greater diversity of combinations among parent canes at lower cost will accelerate progress.

(g) More efficient selection techniques will be devised to permit more rigorous elimination, thereby clearing the way for the processing of larger populations.

(h) Crosses that cannot now be effected will be expedited by the development of techniques for inducing tasseling, controlling time of tasseling, and maintaining pollen viability during long periods of storage.

(i) Further progress will be made in the identification of hitherto unrecognized pathogens and in the devising of techniques whereby potential commercial varieties and breeding canes can be tested for resistance.

(j) Better farming practices will enable higher yielding genotypes to manifest their potentialities.

(k) Ways will be found to reduce the interval between successive cycles of crossing-cum-selection in order to increase the number of generations and thus the amount of progress that the breeder can achieve within his lifetime.

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In the absence of the author the following paper was taken as read.

Paper

THE PROBLEM OF BREEDING HIGH-SUCROSE SUGAR CANE VARIETIES

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INTRODUCTION

Ever since Thomas Fairchild made the first artificial plant hybrid in 1708, plant breeders have been attempting to unite in a single strain the good qualities of several. Selection from populations displaying variability has always been the fundamental technique, and it is still possible to raise very good varieties in this way without any knowledge of the principles of genetics. Sugar cane, with its usually high inter-hybrid fertility, its large and easily-raised seedling populations, and its convenient propagation by cuttings, has for more than half a century proved most accommodating as a source of material for the hybridisation-selection sequence by which the commercial varieties of today have been developed.

"Plant breeding", Professor Harland said at the 1954 Congress of the British Association for the Advancement of Science (4) "has not yet ceased to be an art, and the plant breeder who loves his material and lives with it night and day still plays a most important part. Long may he live, crossing the best with the best and hoping for the best....... But many of our urgent plant breeding problems are beyond his capacity."

The aim of the sugar cane breeder is to develop varieties which will not only increase the production of sugar per acre, but will also allow for production at a lesser price per ton of sugar in the bag. This could be achieved with a good deal more expediency by varieties of fundamentally higher sugar content than by increased cane tonnages in the present range of juice quality. However, it must be borne in mind that richness of juice, which is easily and rapidly assessed in seedling populations, has long been an important criterion in selection work : it has always been the aim (and on occasion the despair) of sugar cane breeders to combine good juice quality with high yield in the field and other desirable characteristics. The extent to which success has been achieved is indicated by the level of excellence of many of the varieties now grown commercially, when compared with those of only twenty or thirty years ago.

Can increased sugar content of varieties, without loss of yield in the field, be expected? Before a rational answer can be given to this question, and in order to appreciate the problems confronting the breeder, it is pertinent to consider some of the characteristics of seedling populations from crosses between the hybrid varieties of today, and the variation in sucrose content of the offspring, in relation to the selection methods used. Such an analysis serves to reveal the limitations of the empirical hybridisation-selection routine and to indicate some modifications by which there is likelihood of more rapid progress being made.

SEEDLING SELECTION METHODS IN BARBADOS

Details of the breeding and seedling testing methods employed at the Barbados Station have been given by Inniss (5), from whose paper it will be noticed that at the First Year Seedling stage, when each new clone is represented by a single stool of cane, a preliminary field selection is made on a basis of yield and other desirable field characteristics. Selected seedlings are then tested for juice brix by means of the hand refractometer, since such testing can be conveniently carried out on the spot, and mean juice brix readings are well known to show consistently high correlation with sucrose in juice figures (6, 8). Eliminations are made, therefore, from the preliminary selections on the basis of low juice brix. Final First Year selections are made after a re-consideration of the whole population of field selections on a basis of all available data on yield, juice brix, growth type, extent of arrowing, cane rotting and absence of disease symptoms. Such final selections are issued with their permanent serial B. numbers, and are propagated for further trials.

For the purpose of the present study, seedling selections made at the 1955 reaping, of which the survivors after the elimination stages represent the B.55 series, have been used to demonstrate the characters of the population variation in juice brix. There were 701 preliminary selections, from a field planting of 9,890, a percentage of approximately 7.1. Of these, 124 were eliminated on account of low brix readings, and from the remaining 577 there were 360 final selections, or approximately 3.6 percent of the total field planting. The preliminary selections showed a mean brix figure of 20.1%. After field eliminations, the remainder averaged 20.6%, and the final selections 20.8%. To complete the picture of the population, it may be recorded as a matter of interest that the preliminary selections averaged 53.6 lbs. per stool, those remaining after the field elimination, 54.0 lbs., and the final selections 59.1 lbs. per stool.

VARIATION IN JUICE BRIX OF A SEEDLING POPULATION

From the data recorded at the reaping of the First Year Seedlings described above, distribution curves have been constructed to show the percentage occurrence of seedlings in the different brix classes for the preliminary selections (numbering 701), the field selections (577) and the final selections (360). These are presented in Figure 1.

The curve for the preliminary selections shows a typical random distribution for a character limited physiologically in its upper range, i.e., a somewhat skew curve with longer tail in the lower range. Similar curves for unselected populations have been described elsewhere (10). The curve for field selections shows the expected change in form due to the elimination of the bulk of the low-brix individuals (the few retained were selected primarily for breeding). At this stage it is interesting to recall the mean weights for preliminary selections and field selections after elimination of the low-brix individuals. These were 53.6 lbs. and 54.0 lbs., respectively. Evidently there is no indication of a negative correlation between weight of stool and brix of

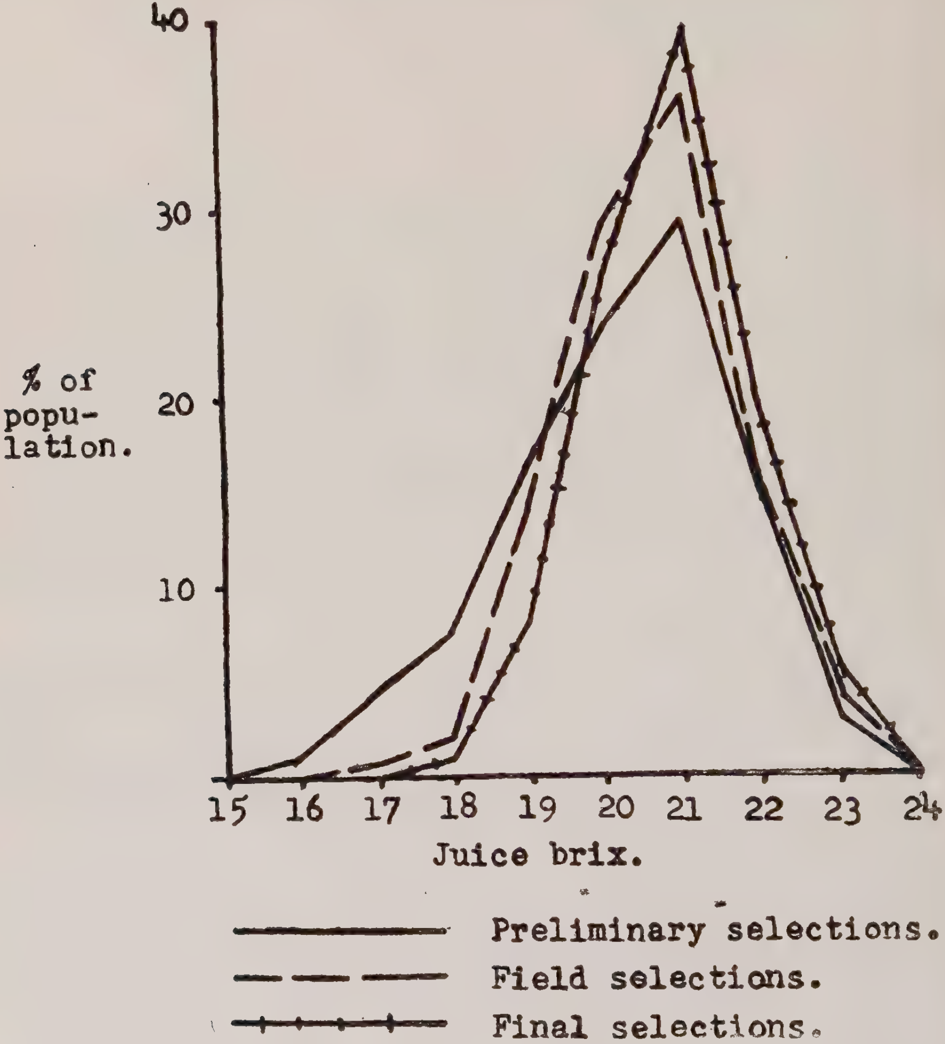


Fig. 1. Variation in seedling juice brix.

juice here, since elimination of the low-brix group has not reduced the mean weight of the remaining selections. There has been some discussion elsewhere as to whether such a correlation occurs in seedling populations (11, 13), and the data here serve to corroborate the writer's expressed view that if any such correlation can be demonstrated statistically, it is so low as to be, for practical purpose, non-existent. Bearing in mind the masking effect of environmental variation on the important range of distribution for weight and brix figures brought about by gene segregation, on which effective selection is based, it will be evident that a low correlation between these can have no real value as an aid to selection, no matter whether it be statistically significant or not. Indeed, in illustration of the adage that statistics can be a useful servant but a bad master, it is a chastening thought that correlations as high as 0.3 may occur quite by chance sometimes for a hundred or more variables between characters which are known to be quite independent (7).

The third curve in Figure 1, for final selections, shows a further slight shift upwards in brix values, due to the elimination at this stage of some border-line cases. Brix mean per seedling is raised here from 20.6% to 20.8%, but at the same time mean weight per stool increases, from 54.0 lbs. to 59.1 lbs., showing that at the final selection stage weight was the more important selection criterion.

Perhaps the most significant point illustrated in the curves in Figure 1 is that although the populations at the different selection stages differ in mean juice brix value, all have their highest percentage occurrence of individuals at the same point in the brix range—20.5 to 21.4 represented by 21 in the diagram. The percentage occurrences at this range increase successively, of course, with the selection stages, and the shape of the curves in the upper brix ranges is closely similar, as the same individuals represent each population at the higher brix values.

The brix distribution in the population of preliminary selections, shown in the basic curve in Figure 1, is perhaps rather remarkable when it is realised that these seedlings represent an unselected population so far as brix values are concerned. More than 47% of the seedlings, for instance, occur in the brix of range 21% and over. The facts indicate that continued selection in Barbados over a period of more than twenty-five years has resulted in the evolution of parent varieties which are able to endow relatively good juice quality to a high proportion of their offspring. However, if sucrose content in new varieties is to be materially improved, only the individuals with exceptional juice quality can be considered for selection, and the curves show clearly that such individuals make up only a very small proportion of the population. There is no evidence to show that weight of cane is not quite independent of juice quality in its distribution in seedling populations in the general breeding programme, and as resistance or immunity to some disease is often associated with low juice quality, it is evident that the chances of selecting a seedling of exceptional juice quality which is also desirable in other respects is very low indeed so long as seedling populations with qualities such as those described are being produced from the parent varieties used in breeding work. Conscious of these considerations, the Hawaiian geneticists have implemented their philosophy of breeding by increasing considerably the numbers of seedlings tested annually (12). While it is admitted that such a policy is justified by the evidence available, the object of the work in Barbados is to investigate an alternative approach to the problem which might be equally as effective or more so, and at the same time more economical.

GENETICAL CONSIDERATIONS

The parent varieties used for breeding at the present time are, for the most part, complex heterozygous polyploids and aneuploids : most of them are interspecific hybrids, though all except those in the early stages of particular breedin lines have a high proportion of *Saccharum officinarum* in their genealogy. Genes concerned with good juice quality are almost entirely inherited from the *S. officinarum* ancestors, for the other *Saccharum* species used in sugar cane breeding to endow vigour, disease resistance and other qualities are extremely low in sugar content. Chromosome behaviour at the 'nobilisation' stages accounts for the relatively few back-crosses which are necessary before satisfactory juice quality is attained (10). Generally speaking, the hybrid varieties grown commercially at present are up to the standard of the 'noble' varieties (*S. officinarum*) in juice quality, and far outyield them in tonnage of cane per acre. Of the progressive sugar-growing countries, it is only in the tropical areas of North Queensland that 'noble' varieties are still grown to any large extent, and there mainly because erect-growing varieties are required—under the humid conditions there the higher-yielding hybrid varieties tend to lodge and fail to ripen satisfactorily. However, due to the inherent defects of the 'noble' varieties as regards vigour and disease susceptibility, it seems likely that hybrids selected with an eye to the main requirements will replace them within a comparatively short time.

Juice quality, like yield, is a quantitative character, and is polygenic in inheritance. The expected distribution in populations from heterozygous parents has been demonstrated above, and the fact that in such populations yield is, for practical purposes, independent of juice quality has been pointed out. Nor have any measurable morphological characters been shown to be correlated consistently and usefully with sucrose in juice. In his admirable and painstaking investigations with sugar cane seedlings, Barber was searching for such correlations in India as early as 1915 (1). His 'Studies in Indian Sugarcanes' will be familiar to those whose work is concerned with variety improvement through breeding, for they are among the classics of the literature on the subject, and in some respects might well form a model for investigators of the present day. In one investigation, Barber was looking for relationships between sucrose in juice of his seedlings and such features as width and length of leaves, thickness, length and colour of canes, and module (length in comparision with width) of leaves and canes. Although in some cases there were suggestions of a correlation within particular parentage groups, in no case could he demonstrate a consistent relationship which could be used as a basis for seedling selection.

Information now available on the inheritance of polygenic characters in polyploid material provides a genetical basis for such conclusions. On the assumption that a large number of genes is operating, some of which are favourable to the development of good sucrose quality and others unfavourable, the characteristic distribution shown to exist in seedling populations is explained. Genes concerned with sucrose quality would be difficult to enumerate, as the inheritance of this character is concerned with the integration of a series of physiological processes, each of which would have to be determined before a genotypic analysis could be attempted. Each variety is a biological endpoint in which constellations of genes, many of them of small effect, result in a system in balanced interrelationship with the environment. Such constellations of genes make up what has come to be known in recent years as the polygene system, on which selection acts as a process of gene substitution which may impair qualities other than those on which selection is based, due to what Harland has described as 'genetical erosion'. An example of this is the fact that due to such erosion of the vitality system, the modern sugar cane varieties are incapable of survival in a wild state.

Qualitative characters on which selection is based in sugar cane seedlings are few: resistance to certain diseases can be one where resistance and susceptibility are clear-cut, but in many cases there are degrees of resistance. Important selection criteria—yield, sucrose content, growth habit, extent of arrowing and ratooning ability—are quantitative characters, dependent on complicated physiological processes and controlled by polygene systems. Selection with a view to simultaneous improvement in two or more of such quantitative characters, without at the same time allowing deterioration in others, is therefore an operation in which the chances of success by the empirical hybridisation-selection routine would be difficult to estimate. In Hawaii, Warner calculated that the average frequency of occurrence of ultimate commercial varieties in the seedling populations tested in the period 1928-1944 was one in about 136,000 (12), and it is likely that frequencies of that order would be found for other sugar cane breeding programmes.

The value of progeny testing as a means of indicating the most promising parent varieties has long been recognized by sugar cane geneticists. Most sugar cane breeding stations use some form of progeny testing to evaluate their parents, either as producers of high-grade seedlings or in respect of particular qualities, and there can be no doubt that its use has served to raise the general level of seedling populations which are submitted to testing. In the case of juice quality, for example, reference has been made above to the fact that preliminary selections in the B. 55 series in Barbados, hitherto not examined for juice quality, proved to average 20.1% in brix. It is, however, a fact that although sugar yields per acre have shown remarkable improvements in Barbados in the last twenty years, largely on account of the introduction of new varieties, while at the same time gumming disease and mosaic have been eliminated from the Island and growth vigour has been improved so that longer ratooning is possible, nevertheless actual sucrose content of the cane has not been improved generally. The available records show that in 1935 juice qualities of B. H. 10(12) and B. 726, noble varieties which together occupied more than 50% of the area under cane in the Island, were in no way inferior to those of B. 37161, B. 4098 and B. 41211, the major commercial varieties of today.

The above considerations lead inescapably to the conclusion that variety improvement has been brought about primarily by the transference of growth vigour and disease resistance of the wild *Saccharum* types to the basic noble cane genotype without at the same time permitting any serious falling-off in factory qualities. The position is made more clear by the realisation that just as in the modern varieties there has been no actual improvement in the vigour or disease resistance of the wild ancestors, in the same way there is in the hybrids no actual improvement in the juice quality of the 'noble' ancestor. Little more than a compromise has as yet been attained — though a compromise highly profitable to the sugar industry. As an achievement in plant breeding the results can only be regarded as very successful, but in view of the empirical methods which have been and are still generally employed, some of the limitations of which have been pointed out above, it seems unlikely that fundamental improvement in juice quality will be achieved until parent material with better potentialities in this respect is available.

BREEDING FOR HIGH SUCROSE CONTENT—THE SEARCH FOR BETTER GERM-PLASM

All the evidence goes to show that genes concerned with the inheritance of good juice quality are derived largely from the 'noble' ancestors of the hybrid commercial varieties now grown so extensively. Many hundreds of such original *S. offiicinarum* types are available in variety collections, and many hundred others, no doubt, exist in the native gardens of New Guinea, Papua and adjacent Islands where the noble cane is indigenous. The most recent collecting expedition to that region was made in 1951, and the results have been described by Buzacott and Hughes (2). The number of noble or 'near-noble' clones collected on this expedition was 136, and with the exception of a few which failed to survive, these have been established in Australia, where they are being intensively studied in order to assess their value as parents. The varieties Badila and Korpi were obtained from the New Guinea collecting expeditions of 1896 and 1914 respectively: both are noble varieties originally chosen for their high sugar content, and both have been used with great success in the breeding work in Queensland as basic male parents (3). It was with the object of collecting varieties as good as or better than these that the 1951 expedition was arranged by the Queensland

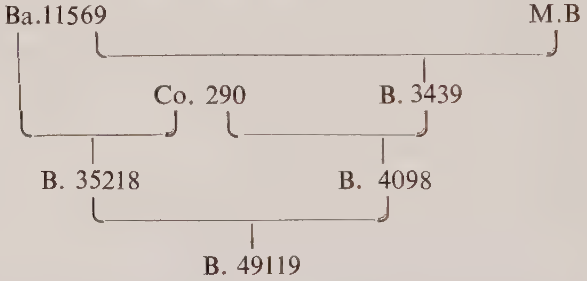
Bureau of Sugar Experiment Stations, and information on the characters of the varieties obtained, particularly on their juice quality, is awaited with interest.

From the genetical standpoint in breeding for good juice quality, there are sound reasons for using high-sucrose noble varieties as male parents in crosses with vigorous interspecific hybrids. They are likely to prove more reliable than hybrid males, in which although juice quality may be good, breeding performance might be disappointing on account of heterozygosity. Certain of the early Barbados hybrid varieties were raised from crosses of this type : examples are B. 34104 (from Co. 281 x B.H. 10 (12) and B. 37161 (from B. 3365 x B. 603). From other breeding stations similar crossing schemes have resulted in such famous commercial varieties as P.O.J. 2878 in Java, Co. 290 in India and M. 134/32 in Mauritius. These, and the Barbados varieties referred to in the same connection, combine vigour and resistance to most diseases with the good juice quality of the noble cane progenitors ; they have also been used with considerable success as parent varieties. Indeed from a cross between two of them (B. 37161 x P.O.J. 2878) was raised the exceptionally high-sucrose variety B. 4362, which has the best juice quality of any recent Barbados commercial variety, and is being grown on a large scale in different parts of the Caribbean area.

B. 4362 occurred as a chance segregant in a small population selected as First Year Seedlings in 1943. As a single stool, it weighed 60 lbs. with the remarkable mean brix figure of 24.1%. It is an example of the occasional really superior individual which is found by the empirical hybridisation-selection routine, but which, for reasons already considered, must occur at less and less frequent intervals as the standard of commercial varieties improves. Moreover, due to the occurrence of heterozygosity and genetic linkage of favourable genes with unfavourable ones, it is a matter of chance whether such a variety, no matter how excellent its own qualities, will prove of any real use as a parent. In the case of B. 4362, which has been used a great deal in breeding on the 'crossing the best with the best and hoping for the best' principle, the results have not been encouraging in regard to breeding for better sucrose content, and on the basis of seedlings reaching the Third Year Trial stage it is less promising than a number of other varieties which are themselves inferior to it in juice quality.

To those who have studied the subject seriously—as indeed to those also who have read the popular literature or dabbled in the breeding of domestic animals—it will be familiar that reliability of breeding behaviour can best be secured through inbreeding or line breeding. The potential value of inbreeding as a means of improving sugar cane varieties has been considered elsewhere (9, 10), and the practical results already obtained by the breeders in Queensland should encourage a wider use of the method in other countries. Gard (3) concludes from a study of his breeding results that "from a heterogeneous collection of male parent varieties tried with the object of imparting high sugar content to the seedlings, those which have best achieved this are the ones which have been inbred from basic high sucrose parents". The most intensive programme of inbreeding with sugarcane is that being carried out in Barbados, where a large number of inbred lines is being developed from high-grade foundation varieties. The evolution of high-sucrose parents of predictable breeding behaviour is an important aspect of the Barbados work, and already third and fourth generation selfs and close inbreds are available in which selection at each stage has been on the basis of juice quality. Some of these inbreds are ready for use in the 1955 breeding season. They will be used in top-crosses with certain breeding varieties, and in some cases in experimental inter-line crosses.

A certain amount of inbreeding has been carried out at the important breeding stations for many years, and several of the world's major varieties are mildly inbred. Some of the later P.O.J. varieties, and certain of the recent Hawaiian seedlings, have been developed from an inbreeding programme, and while in Barbados the accent has been until recently on outbreeding, some recent selections from inbred material in the general series of crosses have shown great promise, and a case has been made out for increased use of the method (10). The extent of inbreeding in the genealogy of the very promising new variety B. 49119 is shown in the pedigree chart below :—



In the pure-line breeding work the degree of inbreeding is much more intense, consisting as it does of selfing or, in the case of desirable male-sterile derivatives, sub-crossing or back-crossing to the male parent. With careful selection for special characters at each stage, and at the expense of some loss of appearance and immediate utility, basic parent material of purified germ-plasm is being built up. From the high-sucrose variety B. 4362, selfs are available whose mean refractometric brix-readings recorded recently are as high as 23.3% and 23.4%, and in the B. 4098 and B. 41211 lines, brix values of 22.2% and 22.0%, respectively, were found for second-generation selfs. Further development of such lines should result in parent material of evident potential value in breeding for high sucrose content, and by these methods an attempt is being made to reduce the empricism so characteristic of present-day sugar cane breeding and to lay the foundations of a scheme by which superior commercial varieties may be produced by design rather than by accident.

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The Chairman requested Dr. A.J. Mangelsdorf to present Dr. J.N. Warner's paper.

Paper

BREEDING FOR INCREASED YIELD IN SUGAR CANE

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INTRODUCTION

Admittedly, breeding for disease resistance is, in fact, breeding for increased yield, but when the day arrives when we have no recognized diseases or pests present in our commercial fields, will that mean that the plant breeders have worked themselves out of their jobs? Certainly not. Pathogenic organisms are not static in an evolutionary sense and the breeders will have to continue to work to hold their gains. But if the recognized diseases were to remain of minor commercial importance, or to require only a small effort to keep in check, what then can the breeders do to increase the yield of sugar?

In Hawaii, we are apparently in the enviable position of having no *recognized* diseases of sugar cane which are of major economic importance. We are not confident that this situation of the past 15 years will be permanent. The industry is therefore, constantly alert to prevent a disease from gaining a foothold.

Up until the early 1940's, eye spot (*Helminthosporium sacchari*) was an important disease on sugarcane in Hawaii and vast areas were seriously affected every year. Resistant varieties were rapidly spread with the result that no eye spot disease can be seen today. Even at the breeding station, where this disease was once common, it is no longer seen in spite of continuous presence of susceptible clones in the breeding collection. Apparently the amount of inoculum present has been reduced to essentially zero.

Among the other recognized diseases, leaf scald, red rot and chlorotic streak are of economic importance only in restricted localities of Hawaii. Ring spot is common in the rainy districts, but since it attacks only the older leaves it is not regarded as serious. Symptoms of ratoon stunting disease have been found, but whether this disease is causing significant yield losses in plantation fields still has to be determined. Except for sporadic outbreaks, the major insect pests of sugarcane in Hawaii are at present well controlled by introdcued parasites.

Of the total number of seedlings germinated and transplanted to the field, over 99 percent are discarded for one reason or another during their first two years of testing. Seedlings which show undue susceptibility to any of the recognized diseases are, of course, dropped, but this category accounts for only a small proportion of the discards. Lack of adequate vigour and apparent well-being in the absence of any apparent disease symptoms accounts for a high proportion of the discards in the early stages of selection. While low vigour could presumably result from purely physiologic inefficiency in the absence of pathogens, we suspect that it is frequently the result of damage by pathogens, known and unknown, whose effects are not associated with clear-cut diagnostic above-ground symptoms. Assuming this view to be correct, our breeding programme in Hawaii is being directed to a considerable degree toward resistance to a complex of deleterious organisms which have not been individually indentified and which manifest themselves individually and collectively in loss of vigour and well-being of the sugarcane plant rather than in clear-cut diagnostic symptoms.

DYNAMIC FACTORS LIMITING YIELD

If we admit that, in addition to dealing with pathogens which result in recognized symptoms, we have to deal with a complex of pathogens causing no such symptoms but which may seriously reduce yields, then we must consider the possible nature and behaviour of these unrecognized pathogens. As for examples, we can only surmise from our experience with recognized pathogens.

Pythium caused the downfall of Lahaina as a commercial cane in Hawaii. There may well be a host of *pythium* strains, and forms of similar root-rotting fungi, present in our soils, no one of which produces an identifiable symptom on present commercial varieties, but some or all of which cause a little damage and collectively result in yield decline. Likewise, root-pitting fauna may have a negative effect on yield, either as a primary agent or in a secondary sense through creating sites for infection by other organisms. Agronomic practices such as weed control may tend to increase such damage to sugarcane through removal from the fields of more normal hosts for the various organisms. Similarly, systemic pathogens, viral, bacterial or fungal, may be present in sugarcane and contributing to yield decline. A case in point is the recent discovery of ratoon stunting disease. There may be many more yield-reducing systemic pathogens with even more obscure symptoms.

Judging from our knowledge of recognized pathogens, the members of the unrecognized group have one important characteristic in common : as long as they are subject to mutation or sexual reproduction, the potential threat of a more virulent form is always present. Thus, any one of these pathogens which produce no clear-cut symptoms has the explosive potential of becoming a major recognized pathogen through mutation or recombination and segregation, or through a change in the environment favouring its multiplication.

Mono-clonal culture of sugarcane provides an ideal medium on which can take place a breeding and selection process for pathogens better able to attack the clone. Important, also, is the rate at which such a process takes place. Micro-organisms breed and multiply at a per-generation rate many times faster than can be accomplished in breeding sugarcane. Thus the "resistant" ratings of a clone of sugarcane to diseases must be expected to need revision toward "susceptible'' when the clone is grown for long periods and over large areas.

In the absence of recognized pathogens, the plant breeder must proceed blindly. He must continually strive for higher yields with the full realization that yield is an integration of a tremendously complex series of factors, acting and interacting in either positive or negative directions with each other and with the environment. At any time, he must expect the sudden increase in importance of a given pathogen. If and when such an event occurs, specific selection pressure for resistance may be applied immediately even without identification of the organism, if seedling populations under test have sufficient inherent variability. This is one of the most important arguments for maintaining a high degree of genetic variability in seedling populations. Doing so permits wide flexibility in meeting new selection pressures imposed by changing conditions and offers continual progress through allowing these widely varying seedlings to integrate all the negative factors which reduce yields. These negative factors may be genetic, physiological or pathological, recognized or not.

GERMPLASM SOURCES FOR YIELD GENES

Commercial varieties of sugarcane are today made up of genes from many sources. Virtually all important hybrids contain genes from *Saccharum officinarum* and *S. spontaneum*. Many also contain genes from *S. sinense* and or *S. barberi*. A few, principally Hawaiian hybrid varieties, also show varying amounts of S. *robustum* in their ancestry.

Bringing together genes from diverse sources, through hybridisation, and selecting among the progenies those individuals best adapted to specific conditions, have led to the establishment of improved varieties in most major sugarcane growing countries of the world. Compared with previous standards, these hybrid varieties offer the advantages of higher or more economic field of sugar. The new varieties have achieved this in some cases through resistance to recognized pathogens, and in other cases through better adaptability to environmental conditions, agronomic practices, and to accumulated resistance to the complex of unrecognized pathogens. Hybrid vigour, the ameliorating of genetic weaknesses from specific germplasm sources and the augmenting of favourable factors through sexual recombination and segregation, has also been of great importance in increasing yield, although hybrid vigour, as a unique influence, can hardly be separated from the previously mentioned constituents of yield accretion. In practice neither can the influence of environment be separated from the effect of the unrecognized pathogens.

What future is there in exploring new sources of germplasm in breeding for higher yield ? Have we reached a ceiling on sugar per acre per month and cane per acre per month as some people have suggested ? A study of the pedigrees of the commercial canes of today shows that the genes for high sucrose, presumed to come primarily from *S. officinarum*, are derived from a mere handful of representatives of this species which happened to be available to the sugarcane breeding thirty or more years ago. Out of this relatively narrow base has come all our modern varieties. Likewise, only a few forms of *S. spontaneum* and the other species have been extensively explored. What genic resources lie in the scores of clones, both noble and wild, which have been added to our collections since the early 1920's we can only guess. A very few of the noble canes collected in 1928 have been explored for breeding potential A few clones of *S. robustum*, collected in 1928 and in 1937, have been used to a considerable extent, but as a group, this species is relatively untested. The same can be said of the other species. It is hardly reasonable to presume that the best possible combinations of genes are to be found among recombinations of the rather limited breeding material used prior to 1928. But, on the other hand, there must still be many chances for better varieties among the recombinations of this material.

The situation outlined above points to the necessity of maintaining permanently the wide collection of germplasm now in existence. Much of it is irreplaceable. The evaluation of breeding potential of this material is a slow process and is never final. A clone may be of no value today, or in one country, but ten or twenty years from now, or in another country, the reverse may be true. Also not to be overlooked is the need to augment the present collections of original sugarcane clones and their wild relatives. Especially important in this connection are the original noble canes (*S. officinarum*) which do not survive in the wild. Their original source is in the native subsistence gardens of S. E. Asia, Melanesia and Polynesia. As civilization creeps through these areas, the natives give up their culture of these chewing canes with the result that valuable clones may be lost unless sugarcane breeders take steps to collect and preserve this material.

EVALUATION OF NEW SOURCES OF GERMPLASM

One of the keys to breeding for higher yield is to survey available sources of germplasm for those genes and gene combinations which result in better individuals. One of the characteristics of a good breeding programme in sugarcane is the achievement of a proper balance between, first, the breeding of better parental material for future years, and, second, the production of populations of seedlings among which to select commercial varieties, thus to satisfy the needs of the moment.

In areas where successful breeding programmes are in operation, introduced noble canes, wild canes, and even foreign hybrids when crossed with local parents, produce a relatively low order of progeny. These foreign and wild blood lines must be diluted down to one-fourth or one-eighth (or less in the case of some wild canes) before their usefulness in breeding commercial canes can be determined. To accomplish this dilution of unadapted blood lines through the normal bi-parental cross-selection cycles would require from two to six or eight years per cycle, depending on how critical the selection is to be before the next step in breeding.

Another factor, often lost sight of is the specificity of parental combinations. A new, unadapted blood line may prove promising in some combinations, worthless in others. This emphasizes the need to try new blood lines in a diversity of combinations to be reasonably sure of an adequate evaluation.

In Hawaii, these problems have been met with the use of "area cross" and "melting pot" techniques in cases where it is desired to explore the breeding potential of new sources of germplasm, especially "wild" material. The procedures may be outlined as follows :

1. *First Year* : Use wild clone "A" as a male in an area cross with several adapted females.

2. *Second Year* : Grow hybrid progenies in seedling nursery (we use bunch planting). Cut tassels from desirable plants for breeding, bulking those having a common wild parent, but with different adapted female parents. Segregate tassels into males and females.

(a) Males. Use bulked males as source of pollen for an area cross with adapted females (which would likely be different from those used the previous year).

(b) Females. Use in melting pots.

3. *Third Year* : Grow quarter-bred progenies in seedling nursery. Proceed as in second year, segregating males and females, but in each group bulking tassels with common wild ancestor.

4. *Fourth Year* : Grow eighth-bred progenies in seedling nurseries.

At the end of the fourth year, the seedling populations may be evaluated as to whether a further backcrossing to an adapted type is warranted or whether individual selections are justified. At this point the parentage records of the 1/8-wild seedlings would fall into two categories.

(a) "Wild cane A 1/4 x ?" where tassels from the line in question were female in the last cross and were put into the melting pot.

(b) "H XX—WXYZ x Wild Cane A 1/4" where the bulked male tassels of A 1/4 individuals were used in an area cross with adapted females.

These techniques have permitted rapid dilution of unadapted germplasm. In the example cited, the individuals selected from the "Wild Cane A 1/4 x ?" population will have 1/8 of their germplasm from Wild Cane A and 7-8 from unknown, but adapted, proven parents. Selections from "H XX — WXYZ x Wild Cane A 1/4" group will be 1/2 H XX—WXYZ, 1/8 Wild Cane A and 3/8 unknown but adapted, proven parents. The inability to identify the "unknowns" in such parentages is relatively unimportant as long as we know that they were good adapted parents.

Another useful technique is to make sub-matings among hybrid, quarter-bred or eighth-bred canes having a common unadapted source of new germplasm. This is a particularly useful technique for recognizing unique advantageous recessive genes which may be available from a new germplasm source. Actually until relatives are mated (or selfs made) such genes remain ineffective and unrecognized.

The "melting pot" technique, in itself or in connection with the above techniques, is a useful means of accomplishing a two-fold job : first, untried breeding material may be evaluated as female parents in a large number of combinations at minimum cost ; secondly, the maintenance of ample genetic variability among seedlings under test is ensured to meet changing and unpredictable selection pressures which may arise as a result of changes in the pathogen complex. Another important advantage of the melting pot is that it allows economic use of a wider range of parents, resulting in an increased number of combinations, than is possible in bi-parental crossing. Restriction of parental choice to the most phenotypically elite canes may lead to dead ends. In breeding for increased yield, canes with one or two disqualifying characteristics may well prove to be among the better parents. Melting pots allow a wide use of many potentially desirable canes as parents at minimum cost. Separate melting pots for specific purposes can also lead to increasing the concentration of desirable genes for different environmental conditions. The various aspects of the melting pot technique have been discussed in earlier publications.*

SEEDLING PROPAGATION AND TESTING

Seedlings which prove to be superior to existing commercial varieties are extremely rare where these varieties have been bred and tested in the particular environment. Such seedlings represent the chance uniting of two gametes which carry appropriate genes to ameliorate each others deficiencies. The need for maintenance of ample genetic diversity and variability in seedling populations should be readily apparent from the previous discussion. Also apparent should be the need to raise large numbers of seedlings in order to stand a chance of including the rare segregants of commercial promise. Both of these aspects of propagation and testing have been fully discussed in earlier publications.**

In order to handle large seedling populations within budget limitations, suitable techniques must be devised. In Hawaii we have resorted to the bunch planting method. Admittedly this method has its disadvantages, but it does insure a maximum number of seedlings per acre. In a commercial variety, one of the major components of yield is the ability of the variety to produce a maximum number of stalks per acre. In other words, one of the major selection criteria must be the ability of each cane stalk to compete and survive in a dense stand of cane. Bunch planting provides this sort of competition from the start, while space planting allows non-competitive types to be subjected to further selection because they may appear desirable in the absence of severe competition. While bunch planting is far from perfect in preventing this situation, those weak individuals which are not aggressive competitors stand less of a chance of being selected than when they are given ample protection through spacing.

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* Mangelsdorf, A. J. Sugar Cane Breeding in Hawaii—Part II. *Hawaiian Planters' Record* 54 (3) : 101-131. 1953.

Warner, J. N. The Evolution of a Philosophy on Sugar Cane Breeding in Hawaii, *Hawaiian Planters' Record* 54 (3) : 139-162. 1953.

Warner, J. N. The Philosophy of Sugar Cane Breeding in Hawaii. *Proc. of the 8th Cong. of the I.S.S.C.T.,* pp. 410-414. 1954.

Warner, J. N. Techniques of Breeding and Testing Sugar Cane in Hawaii. *Proc. of the 8th Cong. of the I.S.S.C.T.,* pp. 415-422. 1954.

It seems important to provide ample competition for seedlings at all early selection stages. Needless to say, when the selector has to fight his way through a field of seedlings growing in small plots, the task is not the most pleasant. The fact remains that the breeder who gives more than normal spacing to seedlings, in order to see them easily in the field, stands the chance of selecting types which will not give the highest yield when grown commercially under the more severe plant to plant competition needed for maximum yields.

Another important consideration in breeding and testing for increased yield is the need to emphasize this very objective. To breed for increased yield we must select for increased yield. Selection criteria must continually be re-examined to insure that no artificial barriers which would eliminate worthy candidates are erected in the selection scheme. We must let the cane tell us through sound experiments how much it can yield. To say this cane is too slender, that cane is too thick, another cane is too open or not erect enough, may lead to discarding the very cane which offers increased yield potential. We, as plant breeders, are all guilty of favouring particular types of cane at selection time, but too often more severe restrictions are placed upon the visible features of a new cane than on how much it can yield. We must rely on the flexibility of agronomic practices to adapt themselves to varying plant types if we are going to achieve maximum yields, granting that the economics of changes of practice must be evaluated in terms of yield. We must not impose fictitious or artificial restrictions on the plant at selection time. The range of selectable types must be kept as broad as possible, commensurate with sound experimental evidence.

Along this same line, that of selection criteria, should be mentioned environmental interactions. A decision to save or discard a given seedling, based on information from one planting at a single location in a single year, must be regarded as hazardous at best. In the earliest stages of selection such a practice may not be avoidable. However, as soon as possible, each seedling in the testing programme should be located at a number of representative locations in commercial sugarcane areas. A range of locations should provide a sample of the various negative factors (including the pathogen complex) which may be operative in the commercial fields. This is important under the concept that we must rely on the plant to integrate these negative factors. The selector should make use of information from all locations and from other years' plantings to weight his decision as to whether to discard or save the particular seedling he may be inspecting. This requires a suitable up-to-the-minute record-keeping system which can be summarized for the selector and carried in to the field at selection time. Such a system allows the selector to recognize canes that have a desirable range of adaptability, as well as special-purpose canes.

Whether to test varicties under current established fertilization levels and agronomic practices, or under higher levels, is a problem which is of particular importance in breeding for increased yield. At established levels and practices, the point may be reached where ample contenders attain the yield level of the established standard for which the agronomic levels are optimum. However, if fertilization levels are raised, certain of the contenders may benefit disproportionately and the result be higher and more economic yield. Unless selection and yield trials are conducted under highly favourable fertilizer levels and agronomic practices, this possibility would be discovered only by chance.

The final stage of testing that of replicated yield trials, need be mentioned only to complete the picture. Proper tests must be conducted over a range of years and locations, interpreted with the aid of sound statistics and accurate observations during the progress of the crop. Accumulated information must be carefully evaluated prior to making recommendations for commercial plantings In so far as possible, milling qualities, fiber analysis and allied information, should be used in arriving at the final decision.

CONCLUSIONS

In breeding for increased yield, in the absence of recognized diseases, the following factors need particular emphasis :

1. Unrecognized pathogens which result in no specific symptoms have the explosive potential of becoming major recognized pathogens at any time.
2. Paralleling the breeding for improved commercial varieties, a share of crossing work should be devoted to exploring new germ-plasm sources efficiently and developing new potential parental material.
3. Techniques of breeding should ensure ample genetic diversity in seedling populations.
4. Large populations are necessary to include the rare seedlings which are superior to established commercial varieties.
5. All stages of selection should be under conditions of plant-to-plant competition comparable to those in commercial fields.
6. Seedlings should be tested over a range of environmental conditions in commercial sugar cane areas and selected at each stage with the aid of all the accumulated information on each seedling being examined.
7. Selection criteria should have sound basis in experimental evidence. Artificial criteria and opinions have no part in selection for increased yield. When breeding for yield, selection must emphasize yield.
8. Final yield trials should be free of bias and carefully interpreted with the aid of complete information.

DISCUSSION

Mr. R. R. Panje stated that it was desirable to have an exchange of views on the policies underlying the breeding work on sugarcane in different countries. He pointed out that there was a striking difference of opinion among cane breeders on the question whether the breeder should aim in successive generations at greater uniformity with gradual improvement in progenies through selfing and sib-crossing, or whether he should work towards a more and more heterozygous progeny in order to increase the variation and the chances of getting rarer desirable combinations in gene assortment. He wanted to elicit the opinion from the breeders.

Mr. K. L. Khanna asked whether the breeder actually bred for qualities like sugar, yield, disease resistance etc., or whether it was only a case of selection for the characters. He cited instances of the same variety showing wide variation in yield and sugar and felt it was not clear whether the high yielding or high sugar capacity was the potential of the variety or had come from outside. He pleaded for having a chain of breeding stations and laid emphasis on screening for disease resistance and standardisation of methods particularly with reference to red-rot.

Dr. H. M. Tysdal felt that the breeding programme in Hawaii was well organised and it was desirable to have a larger progeny in order to get the required genotype. He agreed that inbreeding had its uses.

Dr. T. S. Raghavan declared that sugarcane breeding was fundamentally different from that of other crops. Inbreeding as a tool was of no use in sugarcane. As regards selfing, most of the *S. officinarum* varieties were pollen sterile or self sterile. Even if selfs were obtained, there was a high rate of mortality due to the presence of lethal genes. In most cases in sugarcane, parthenogenesis was the rule and the derivatives were diploids. Chromosome elimination played a large part in breeding. All these increased the element of chance in sugarcane breeding and there was no use in selfing or inbreeding.

Dr. B. K. Mukherjee felt that in addition to climate, soil condition and manurial and cultural practices played an important part in determining the yield. Breeders must evolve varietiesh wich should show response to small dosage of fertilisers and limited supply of water. He thought that one breeding station to cater to the varied needs in India was not sufficient.

Mr. N. L. Dutt congratulated Dr. Mangelsdorf on his paper. Regarding pollen fertility, he felt that sugarcane pollen lost viability in two days though it might germinate in artificial media for ten days. He differentiated between commercial and fundamental breeding. It was necessary to bring sugarcane breeding in line with that of other crops. It may be possible by patient work to raise pure lines. This was a long range programme and commercial breeding could not wait for the results. The problem of evolving better commercial varieties was urgent and hence commercial breeding utilising the needed parents must go on, even if it was " hit or miss ". The melting pot method or any other method was welcome if it can give commercial types. On the question of regional selection of varieties, he felt that sending out larger numbers ot seedlings was a better alternative to supplying fluff. Under unfavourable conditions of seedling work in subtropics, there was every risk that valuable seedlings might be lost in their early stage when they are delicate. At Coimbatore, where ideal conditions prevailed for seedlings the loss of such seedlings could be prevented.

Mr. Harbans Singh remarked that seedlings should be raised on the type of soil and climate under which they were to be grown and it was not the correct approach in a vast country like India to restrict raising of seedlings at one place.

Dr. R.K.Tandon said that there was a need for evolving varieties resistant to waterlogging and to insect pests. He felt that selection of seedlings should be done under local conditions in each area.

Dr. P. C. Raheja emphasised the need for physiological specialisation in breeding. He thought that this can be effectively tackled in a polyhybrid as well. According to him many of the characters were highly correlated which indicated that genetics played its part in the normal way.

Mr. J. T. Tapay stressed the need for importing varieties from all countries for utilisation in breeding and urged the exchange of parental stocks.

Dr. R. D. Rege was of the opinion that hybrid varieties though good in sugar content tended to be more fibrous and this reduced the extraction.

Mr. G. F. Clarke felt that to ask breeders to produce varieties for low fertilizer levels, for waterlogged areas, etc., is to demand too much from them. In those cases where the limiting factor was capable of being controlled or overcome by the grower, the breeder should not be asked to breed canes for those factors. There are factors which are uncontrollable and the breeders can do their job well, if they were allowed to concentrate on these.

Dr. Evans was of the view that some of the problems posed 30 years ago still remained unsolved. The point whether yield and sugar were correlated or not should be settled. Dealing with the question of breeding policies, he said that inbreeding was desirable in sugarcane. The range of variation was greatly increased by outbreeding, but there was bound to be difficulty in selection, and the chances of missing a large number of promising types was great. He agreed with Mr. Dutt that the two avenues—fundamental and commercial breeding—should be followed.

Replying to Dr. Evans, Dr. Mangelsdorf stated that inbreeding was not successful in Hawaii. The variety P.O.J. 2878, he said,was subjected to selfing and crossing, but whereas individuals superior to P.O.J. 2878 were obtained by the latter method, none so good were obtained by the former method. This reduced the interest of breeders in selfed progeny in Hawaii. Dr. Mangelsdorf agreed with Dr. Evans that when the study of the progeny was not sufficiently intensive, the chances of a large number of good types being lost was greater. Regarding centralisation of breeding work, Dr. Mangelsdorf agreed that it was important to test a large number of seedlings under varied ecological conditions and whether fluff or seedlings of varieties should be sent to regional stations would depend on local circumstances. In Hawaii, the seedlings used to be raised from fluff in plantations and sub-stations for many years, but centralisation of breeding work at the Experiment Station was found to be definitely advantageous ; accordingly after a trial over a few years, the sending of fluff to regional stations was stopped. Answering Mr. K. L. Khanna, Dr. Mangelsdorf said that in view of the dynamic nature of disease pathogens, it would seem desirable to place reliance on genetic diversity in sugarcane breeding. The greater the diversity, the greater the chances of getting a variety resistant to a given pathogen.

Explaining the system followed in Queensland, Mr. N. J. King said that actual crossing work was done at one Station and fluff was distributed to the special seedling Sub-Stations for raising seedlings under local conditions. Colonial Sugar The Refining Co. had its own breeding station.

Dr. P. C. Raheja gave the information that experiments conducted had shown sucrose and growth to be correlated processes. High sucrose varieties had a tendency to an initially high growth rate.

Answering Dr. B. K. Mukherji's question whether thermal effect or light intensity was responsible for high sucrose or yield, Dr. Evans stated that the total dry matter was known to be dependent on the net incident light energy received. He also referred to Hawaiian work wherein light intensity was found to be the limiting factor in sugarcane growth.

Group II

BREEDING TECHNIQUE

The chairman invited Mr. Alfonso Gonzalez Gallardo to present his paper.

Paper

SUGARCANE BREEDING IN MEXICO

Alfonso Gonzalez Gallardo and Justo Pastor Ojeda

Campos Experimentales, Union Nacional de Productores de Azucar, S.A. de C.V. Mexico, D.F.

Until the end of the first third of the present century, the cane varieties generally cultivated in Mexico for the elaboration of sugar, *piloncillo* and *aguardiente* were : *Morada* (Black Cheribon), *Rayada* (Striped Preanger) and *Cristalina* (Light Preanger) giving a medium yield of 60 tons of cane per hectare which, though low, was profitable at that time.

The sanitary condition of the cane plantations was good and the pests and diseases lacked economic importance at such a low rate that Dr. Melville T. Cook, Phytopathologist of the Experiment Station of Puerto Rico, in his work on the geographical distribution of sugarcane diseases, quotes only 3 known diseases in Mexico : Red rot (*Glomerella tucumanensis Speg.*), Arx and Maller (*Colletotrichum falcatum*), Rind disease (*Melanconium sacchari*) and the pineapple disease (*Thielaviopsis paradoxa*), although noting that probably a more detailed study would reveal a larger number.

As a result of a trip made in 1929 through the sugarcane world by the late Manuel Perez, General Manager of the Ingenio Atencingo, Pue., in the basin of the Rio Balsas, and due to the connections of the officials of the Ingenio Los Mochis, Sin., in the western coast with the cane technicians in Louisiana, U.S.A., a collection of commercial varieties was imported almost simultaneously to both places, from which P.O.J. 2878 and Co.290 were selected to be released for commercial cultivation in substitution of the noble varieties that at that time showed evident signs of declination.

With the introduction of the improved varieties which have come to take a prominent place in our cane fields, some of the existing diseases have acquired economic importance and it is quite probable that we have introduced new pests and diseases which did not exist before in the Mexican cane fields.

During the time elapsed since the introduction of the new commercial varieties was started, the production of cane for the elaboration of sugar and the sugar manufactured are given in Table I. Besides, we produced about two million tons of cane for "piloncillo" and more than one million for other purposes.

TABLE I

Year	Hectares cut	Cane ground Tons	Tons cane/Ha.	Sugar Tons	Sugar yield % cane
1931	52,643	2,885,2850	54.8	243,015	8.42
1932	50,452	2,529,641	50.1	214,620	8.48
1933	48,634	1,816,715	37.3	182,666	10.06
1934	51,646	1,953,760	37.8	183,762	9.41
1935	54,194	2,833,078	52.3	260,242	9.19
1936	63,632	3,264,666	51.3	303,654	9.30
1937	56,455	2,992,645	53.0	277,655	9.28
1938	61,423	3,309,997	53.9	305,602	9.23
1939	66,165	3,504,185	53.5	331,482	8.72
1940	58,426	3,523,344	60.3	292,334	8.30
1941	63,009	3,505,153	55.6	328,507	9.37
1942	78,724	4,610,378	58.5	419,780	9.11
1943	82,150	4,383,637	53.4	412,213	9.40
1944	82,587	3,626,902	43.9	387,837	10.69
1945	80,925	3,964,178	49.0	373,106	9.41
1946	98,781	4,217,610	42.7	376,617	8.93
1947	107,749	5,549,176	51.5	490,636	8.86
1948	126,689	6,800,860	53.7	611,767	9.00
1949	141,866	7,170,810	50.7	645,418	9.00
1950	142,122	6,759,061	47.6	589,681	8.72
1951	152,996	7,621,825	49.8	665,823	8.74
1952	158,496	7,907,484	49.9	691,145	8.74
1953	163,393	8,551,567	52.3	779,262	9.11
1954	183,169	9,101,540	49.7	828,702	9.11

The study of the above data shows that in spite of the fact that year after year new lands were opened to cane cultivation and a more general use of chemical fertilizers was made, the unitary field yield was hardly maintained, that is, it actually decreased.

In fact, the P.O.J. and Co. varieties have already shown obvious symptoms of disadaptation and less resistance to pests and diseases in some of the country's cane areas. Moasic has spread in an alarming manner in some regions; the borer causes significant economic damages in the Huastecas and Sinalea areas, marginal in cane culture, and important damages caused by the yellow aphid (*Sipha flava*), the froghopper (*Aeneolamia sp.*) and the white grub (*Phyllophaga sp.*) are suffered in several areas.

The deficit balance between production and consumption started during the quinquennium 1936-1940: this was overcome during the following lustrum with a substantial increase of cultivated areas and the more ample use of fertilizers, and brought to consideration the need for increasing the unitary field yields by means of, among others, the introduction and breeding of new varieties of higher yield.

The breeding work for new cane varieties adapted to the Mexican environment, was started in 1943 by the Secretaria de Agricultura y Fomento (Agriculture and Promotion Bureau) in the small property of the Ingenio El Potrero S.A., where a bank of genetic material formed by 102 varieties selected from the Canal Point's collection by Dr. E. W. Brandes, of the United States Department of Agriculture, was established.

Mr. D.Mc. H. Forbes, Field Superintendent of El Potrero at that time, was appointed by the Secretaria de Agricultura to take charge of the conservation of the bank and to start breeding work having achieved 51 varieties P.M. (Potrero Mexico), 10 of which seem to have good commercial characteristics; 3 others, equally good, are susceptible to mosaic; and one, namely P.M. 100, is poor in sugar but of high tonnage, and might possibly serve as parent in case it gives fertile flowers. These activities were discontinued several years ago.

The convenience to stabilize the Mexican sugar industry by synchronizing the production with the increasing demand of the domestic market, induced the Bank of Mexico to sponsor a general survey of the Mexican sugar industry which was effected during the years 1946-1947 by technicians hired by Ford Bacon & Davis, Inc. As a result Dr. George Arceneaux advised to give breeding a special preference in order to produce cane varieties better adapted to the diverse climatic conditions, soil and cultural practices of the 16 cane regions included in the territory of the Republic of Mexico,—14 regions and 2 subregions as well as to the climatic conditions. Data of representative climatological stations are shown in the attached graph. The soil characteristics are discussed in a related paper which has been presented to the IX Congress and discussed under Soil Section.

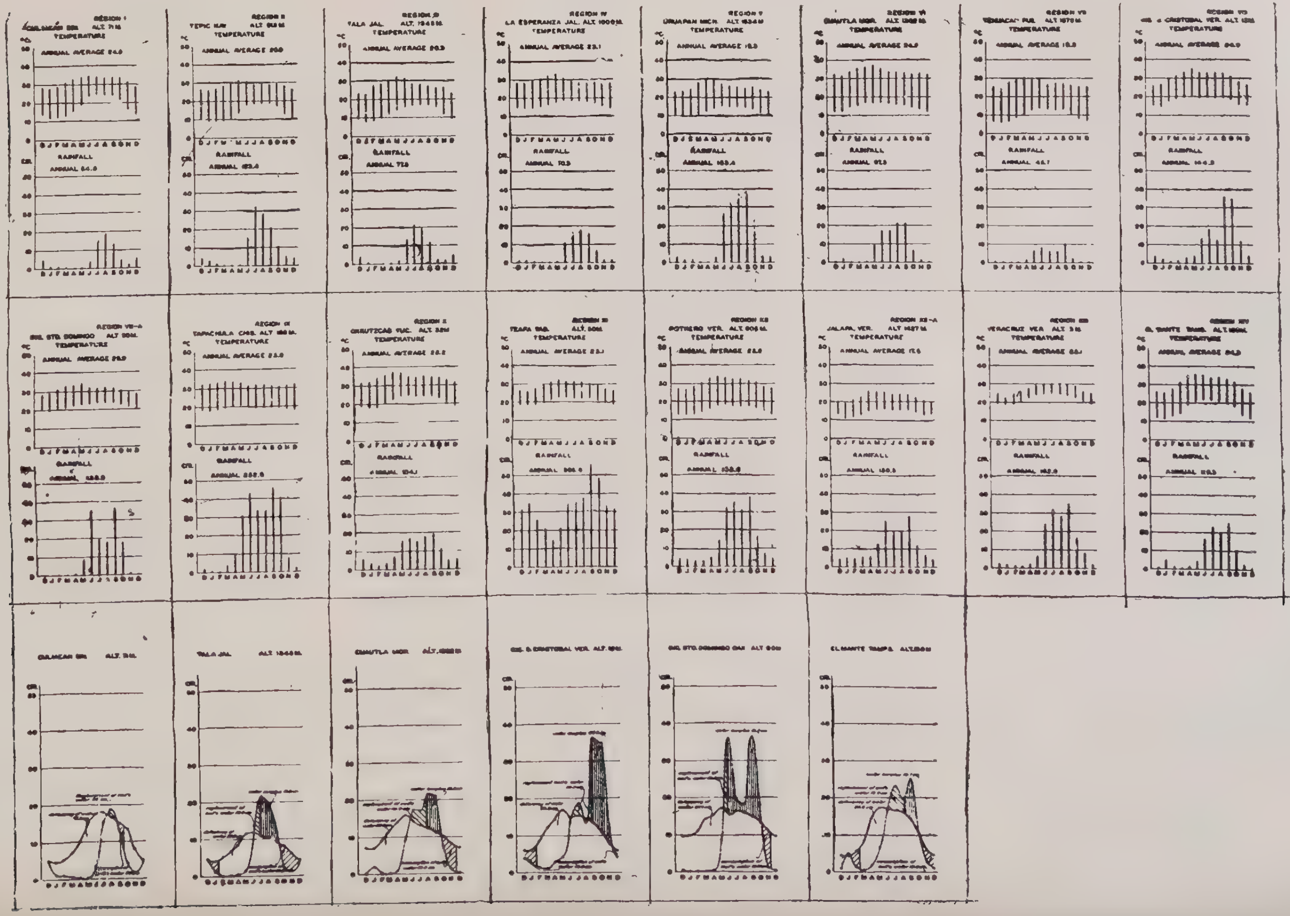
After the establishment of the Oficina de Campos Experimentales of the Union Nacional de Productores de Azucar, it became imperative to reassume the activities in order to create Mexican cane varieties, and it was decided to establish a breeding field at the Estacion Agricola Experimental de Cultivos Tropicales at Rosario Izapa, Chis., on the right bank of the Rio Suchiate, at the border of Guatemala, 20 kilometers from the City of Tapachula.

The field is located at an altitude of 425 meters, has excellent irrigated soils and a very adequate temperature for the cane to produce every year tassels with fertile flowers. It is separated by more than 30 kilometers of woods from the small cane plantations of the aguardiente distilleries of La Magdalena and Venecia, the only ones in the region, and because of its isolation constitutes, at the same time, a quarantine station.

1952 HYBRIDS' GENERATION

During 1951 our Geneticist Justo Pastor Ojeda was appointed to develop the breeding banks and with a supply of the essential equipment, utensils, implements and apparatuses, we made that same year, the first testing crosses which did not yield a single hybrid. For this reason the necessary arrangements were

GRAPH


REGION I
TEMPERATURE
ANNUAL AVERAGE
RAINFALL
ANNUAL
TEPIC NAY.
TALA JAL.
LA ESPERANZA JAL.
URUAPAN MICH.
CUAUTLA MOR.
TAPACHULA CHIS.
TEAPA TAB.
POTRERO VER.
JALAPA, VER.
VERACRUZ VER.
°C
CM.
D J F M A M J J A S O N D

made for our Geneticist to make a visit to the experiment stations of Canal Point, Fla., Grand Isle, La and Belle Glade, Fla., during the breeding season of 1952, with the object of bettering our breeding technique.

Moreover, we hoped to improve our knowledge and experience with the stay of our Geneticist in Hawaii, since February 14 to April 9th, where he studied and practised all the operations, records and technical details followed in that region, in addition to which we hoped to receive the visit of Dr. Arceneaux for a period of 5 weeks starting August 15th, 1955.

(a) *Crosses.* The breeding activities were started in firm during the fall of 1952, still without a defined programme, having achieved 44 crosses.

(b) *Seedling Flats.* 62 germinating flats of 14″ × 20″ × 4″ were planted with the hybrid fuzz, obtaining 53,802 seedlings.

(c) *Nurseries.* During the Winter 1952-53, approximately 6 weeks after planting, the nurseries were formed in 33 ridges of 1.20 wide by 15 meters long, transplanting each seedling individually at a distance of 10 cms. in all directions.

(d) *Selection by Mosaic.* In the Spring of 1953 all the seedlings in the nurseries were inoculated with needle, rooting out all those that caught the disease.

(e) *Transplant to Field.* In the Summer of the same year 1953, 7,448 seedlings were selected by their agronomic characteristics, being transplanted individually in rows at a distance of 1.20m. and 60 cms. from plant to plant.

(f) *Cutting of Seedlings.* Towards the end of the Autumn of 1953 the cane was cut with the purpose of making later, the selection of the desirable hybrids in the ratoons, taking into account the Brix and agronomic characteristics.

(g) *Selection of Hybrids.* In the Autumn of 1954, 60 hybrids were selected, in comparison with the interspaced checks of the region's commercial canes and were designated Mex. 52 with the corresponding progressive number.

BREEDING PROGRAMME

With the object of establishing in Mexico a modest but comprehensive breeding programme, which will allow us to reach practical realizations, we requested the University of Puerto Rico to have Dr. Policarpo Gonzalez Rios, Geneticist of the Rio Piedras Experiment Station, assigned to study the Mexican conditions and extend us his technical advice. The authorization was granted by the University's Dean, Dr. Jaime Benitez and by Doctors Arturo Roque and Bernardo Capo, Director and Sub-Director of the Experiment Station.

During the survey made with Dr. Gonzalez Rios, it was possible to draw a programme to produce 100,000 annual seedlings and organize the selection work following lineaments similar to those of Hawaii, where they have satisfactorily solved the economy in labour, technicians, time and money.

The programme outlined includes two fundamental phases : (a) the activities in the breeding field and (b) the selection work in the experimental fields.

WORK AT THE BREEDING FIELD IN TAPACHULA

It will have the following characteristics :

(a) Transplanting in bunches of 5 to 15 seedlings from the over-populated germinating flats to others.

(b) Inoculation of seedlings in the same germinating flats with mosaic virus by friction with Carborundum 80 impregnated with a trituration of mosaic diseased leaves, to root out the seedlings acquiring this disease.

(c) The direct transplanting of the bunches— groups of 5 to 15 plants —to the field along with the soil block, in rows separated 1.50m. and at a distance of 60 cms. from bunch to bunch.

(d) Make two selections of the first vegetative reproduction : The first, in cane plant, during the Autumn and the second , in ratoon, in the summer of the following year.

The operations to be made are 8, as follows :

(1) *Crosses.* From parents duly selected in a number and quantity sufficient to obtain enough fuzz to produce 100,000 seedlings per year.

(2) *Seed Flat.* Planting of a number of germinating flats, enough to produce 10,000 small bunches of 5 to 15 seedlings each.

(3) *Selection by Mosaic.* Inoculation of seedlings in the same germinating flats to pick out those catching the mosaic disease.

(4) *Nursery.* Transplanting in the Spring of the small bunches along with the soil block in rows at a 1.50m. separation and 60 cms. from plant to plant, from where the desirable individuals shall be selected in the Autumn, exclusively by agronomic characteristics.

(5) *First Vegetative Reproduction.* (1.50 *x*1.00 *m Test*). From the canes selected one pair of cuttings, 45 cms. each, are planted with the buds opposed in rows at 1.50m. separation and 1.00m. from centre to centre of the cutting, interspacing a check of the commercial variety of the region each 4 pairs of cuttings.

(6) *First Selection of Hybrids.* In the Autumn of the following year select the desirable individuals by Brix and agronomic characteristics, in comparison with the nearest check assigning immediately the identity number.

(7) *Second Selection of Hybrids.* Once the first Autumn selection is made, the cane is cut and in the Summer of the following year a second selection is made in the ratoon. Some of the hybrids originally chosen will ratoon badly and will have to be eliminated ; others will show desirable characteristics and an identity number should be assigned to each.

(8) *Distribution of Hybrids Mex.* A sufficient number of pairs of cuttings, 45 cms. long, shall be severed from the chosen plants in order to have them sent to the experiment stations. These cuttings are disinfected in hot water at 52°C for 20 minutes, spread to cool and drain and dipped some 10 cms. of each point in a solution of Agallol (Aretan) from ½ to 1%. Then a collection is packed for each of the 7 experiment stations, where we have trained personnel and which cover, more or less satisfactorily, the ecological conditions and cultural practices of the different sugarcane regions in Mexico.

I. *Tapachula, Chis.* At the same breeding station where we shall be able to select varieties suitable for the region of Tabasco, where ecological conditions are in a whole similar to those of Tapachula.

II. *Papaloapan Ver.* For the lateritic soils of the coastal plains and the Gulf of Mexico's watershed.

III. *Matamoros, Pue.* As representative of the black soils of the cane regions of medium altitudes in Morelos, Puebla, and Guerrero and even those of the Pacific's watershed.

IV. *Mante and Xicotencatl, Tams.* For the calcimorphic intrazonal soils of the region of the Huastecas and for those of Campeche and Yucatan. These last will probably require, later, a special test.

V. *Ameca Jal.* Fundamentally for the search of varieties resistant to frost, drought and alkali ; but also as representative of Jalisco, Michoacan, Colima and Nayarit.

VI. *Costa Rica, Sin.* For the chestnut soils of the arid climate of the coastal plain of Sinaloa in the western coast.

VII. *Los Mochis Sin.* Almost at sea level, at the most northern point of the western coast—north of the tropic—with desertic climate of low temperatures during the winter and chestnut soils.

WORK AT THE EXPERIMENTAL STATIONS

With the following characteristics :

(a) A second elimination by mosaic in those areas where the infection has been established. For this purpose, rows of diseased plants will be interspaced so that the aphids will take care of inoculating the hybrids, in order to eliminate those that become susceptible to the local strains of mosaic.

(b) The test of hybrids selected in cane plant and of the second selection in ratoon, except in the extra tropical zones of the north of Sinaloa-Costa Rica and Los Mochis—where only the Summer selection in ratoon will be tested, as the cane planted towards the end of the Autumn does not germinate or germinates badly.

The work to be done includes :

1. *Selection by Plants.*—(1.50 × 1.80m. Test)—Planting the pairs of cuttings

received from the breeding station with the buds opposed, in rows at 1.50m. separation from plant to plant, interspacing a check of the local commercial variety between each 4 hybrids.

2. *Selection by Rows.* (3×5m. *Test*).—With the seed cane from plants selected by Brix and agronomic characteristics in the former test, two rows of each hybrid in single lines, 5 meters long and 1.50m. separation from row to row, will be planted. A row of plants infected with mosaic is interspaced between each pair of rows in the zones where this elimination is to be made and a pair of check rows of the commercial cane, is interspaced between each two pairs of rows of hybrids.
3. *Selection by Lots.* (9×10m. *Test*).—With the hybrids selected in the row test, we plant lots 9 meters wide (6 rows at 1.50 separation) by 10 meters long, interspacing a check plot of the dominant commercial variety between each two lots of rows. The selection is made by agronomic characteristics and test of representative samples in the test mill.
4. *Test in the Commercial Field.*—With those hybrids passing the former test, a statistical test is established in the commercial field in each of the principal types of soils in the zone of location of the experimental station, which shall be conducted in cane plant, ratoon and second ratoon in order to ascertain which of the hybrids may be increased and released to the commercial plantations.

SELECTION OF PARENTS

We have at present a collection of 319 cane varieties. In the three hybrid generations we have obtained to date, the parents from Canal Point have been dominant as can be seen in the following Table :

TABLE II

Year	Number of Crosses	Parents C. P. Female	Parents C. P. Male	Number of seedlings	Bunches trans-planted	Selection 1.50x1.00	Hybrids selected
1952	44	25%	57%	53,802	7,448	—	60
1953	41	34%	66%	137,830	5,915	2,612	—
1954	65	26%	46%	241,973	—	—	—

This circumstance is due mainly to the little knowledge we had on the combinative ability of the different varieties, as well as to the lack of experimental data on the behaviour of the varieties in the different sugarcane regions of Mexico.

As the parents from Canal Point transmit to their progeny a tendency to heavy and early flowering and trashyness, which are serious defects in the commercial varieties, taking advantage of the experience so far gained we shall try to introduce the parents for the subsequent years as follows :

(a) Dr. Policarpo Gonzalez Rios' recommendations : A larger use of Co. 290 in the crosses, as this variety has shown resistance to cold and has demonstrated other good agronomic qualities to adverse soil conditions. It is possible that in combinations with C.P. varieties a more suitable cane for the regions of Ameca, Jal. and the marginal zones of the State of Sinaloa, may be produced.

(b) The commercial varieties that have shown outstanding characteristics in the tests conducted at the different experimental fields, which are, up to now :

B. 34104
B. 37161
B. 37172
Bar. 264
N. Co. 310
Co. 331
Co. 419
Co. 421
C.P. 26/31
C.P. 29/120
C.P. 34/39
Tuc. 1376

(c) The varieties recommended by Dr. John N. Warner, from Hawaii :

Co. 419
Co. 270
Trojan
P.O.J. 2878
C.P. 29/116
Eros
M. 134/32
Q. 47
Q. 49
Q. 50
P.R. 999
B. 4098
B. 4362
H. 32-8560

(d) The varieties proposed by Dr. George Arceneaux :

B. 3337
B. 35269
B. 35247
B. 37226
B. 37261
B. 38192
B. 39274
B. 4098
B. 40272
B. 41242
B. 42231
B. 4327
B. 43337
B. 43391
B. 4455
B. 44167
C.P. 52/1
C.P. 52/36
C.P. 52/43
C.P. 52/98
27 M.Q. 1124
28 M.Q. 1370
32 M.Q. 135
Oramboo
Akbar
Goru
Q. 20
Jason

GENERATION OF HYBRIDS 1953

145 germinating flats were planted with an estimated total of 137,830 seedlings from which we lost 35,625 by the attack of Pythium.

From the 102,205 remaining seedlings, 91,917 were transplanted in little bunches to other germinating flats and 10,288 remained in their original boxes.

The inoculation with mosaic virus was done and only 724 seedlings caught the infection. A total of 5,915 small bunches were transplanted to the fields.

Seedling flats 1953-54

Inspecting newly planted germinating boxes.

Seedlings ready to be transplanted.

Placing male cane beside the female.

The selection was made in the Winter 1954-55 taking into consideration, health, vigour, general appearance, economic development, good thickness of the stalk, growing habit and detrashing of each plant. Furthermore, while cutting the canes selected, all those pipe-like or pithy were discarded, as well as the flowered ones.

In the month of January 1955, a planting for the first vegetative reproduction was made, which occupies an extension of 6,200 square meters including alleys. The percent of germination achieved was very good—98.6%. The present status of these seedlings is satisfactory.

With the experience of this generation and the following of 1954, we intend, in the future, to plant in each germinating flat only the necessary fuzz to obtain a population of 500 to 700 seedlings per box and to suppress transplanting to other boxes in order to gain a month for the definite transplanting to the field.

Besides, we find it very convenient to transplant the groups of 5 to 15 plants along with the soil block, by cutting with a knife the corresponding soil square in the germinating box.

GENERATION OF HYBRIDS 1954

It corresponds to 65 crosses which yielded 4.260 kgs. of fuzz which was planted in 295 germinating boxes, obtaining an estimated total of 241,973 seedlings.

We did not have to regret any loss by the attack of Pythium and only a few seedlings died because of competition or crowding in the overpopulated boxes.

During the course of the month of March the inoculation in mosaic has been done, without having made, until writing these notes, the elimination of the seedlings that caught the infection.

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Mr. N. L. Dutt then presented the following paper.

Paper

SOME RECENT FEATURES OF CANE BREEDING TECHNIQUE AT COIMBATORE

N. L. Dutt and S. A. Hussainy

Sugar Cane Breeding Institute, Coimbatore, India

PLANNED PLANTING OF ARROWING PLOT FOR ADJACENT ROW CROSSING

It is a long standing practice at Coimbatore to have a separate arrowing plot for crossing purposes. Previously the only thought given to the relative position of the various varieties in the plot was to plant the female varieties on the side from which the wind blows so that the pollen of the male varieties is not carried by wind to the female varieties. The change now made is that varieties which come into flower at the same time and possess a similar growth vigour are grouped together. Among these the male sterile 'mother' variety is planted in the central row and on either side of it two male fertile 'father' varieties with whom the former was intended to be crossed are planted. This method of grouping and planting is being followed for all desired parents starting from those, that flower in the first week of October to those that arrow in the last week of November, thus covering the entire crossing season. (Diagram 1)

When the canes grow and begin to flower, half the number of arrows of the pistil parent in the central row and a corresponding number of arrows of the pollen parent on its right side are brought together and tied in such a manner that the former are just immediately above and encircle the female arrows. The remaining number of arrows in the rear side of the pistil parent are tied in a similar manner to the arrows of the male on its left. Partitions made of bamboo matting are placed between the two groupings for protecting the desired combinations from unintended contamination.

In the above method natural free crossing is allowed to take place, with the varieties *in situ*. Occasional gentle agitation of the arrows ensured free mingling and thorough distribution of pollen. Seed is collected from both the female and male arrows. The method is quite simple and has proved to be of great practical value for effecting a record number of parental combinations with the minimum labour and expense.

ISOLATION OF LIVE CANES IN 'ALKATHENE'*

The Coimbatore method of effecting controlled crosses by isolating the parents by ' tile potting ' is well known (Venkatraman and Thomas, 1926). It

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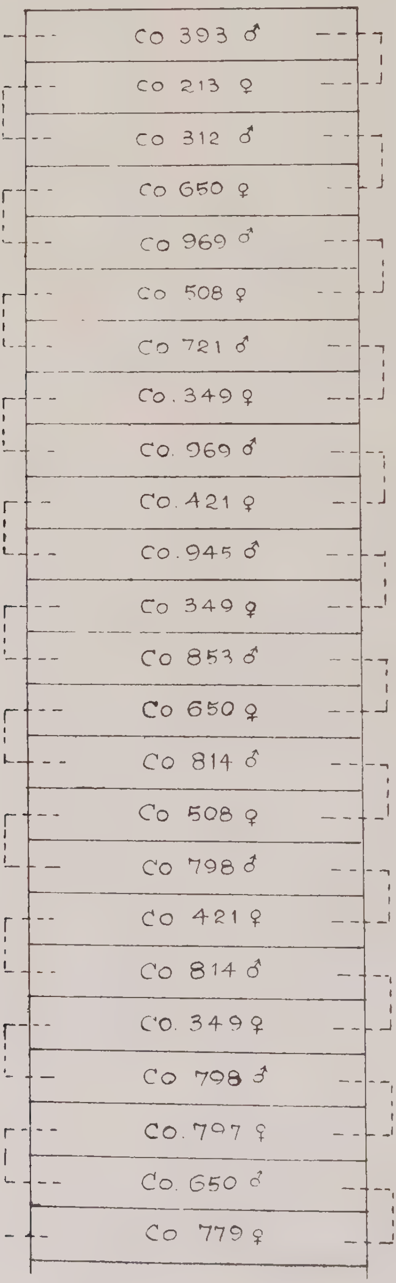
*Alkathene is a polythene film marketed by Imperial Chemical Industries (India), Ltd.

PORTION OF THE ARROWING PLOT TO INDICATE PLANNED PLANTING FOR ADJACENT ROW CROSSING


Co 393 ♂
Co 213 ♀
Co 312 ♂
Co 650 ♀
Co 969 ♂
Co 508 ♀
Co 721 ♂
Co. 349 ♀
Co. 969 ♂
Co. 421 ♀
Co. 945 ♂
Co 349 ♀
Co 853 ♂
Co 650 ♀
Co 814 ♂
Co 508 ♀
Co 798 ♂
Co 421 ♀
Co 814 ♂
Co. 349 ♀
Co 798 ♂
Co. 797 ♀
Co. 650 ♂
Co 779 ♀

has now been found that Alkathene could be used with decided advantage in the place of tile pots, for artificial rooting on standing canes. The method consists in putting an improvised bag of Alkathene to cover two top nodes of a standing cane, and filling it with moist soil or sphagnum moss and tying at both ends (Figs. 1 and 2).

Fig. 1. Alkathene bags put up at the top internodes for inducing rooting.

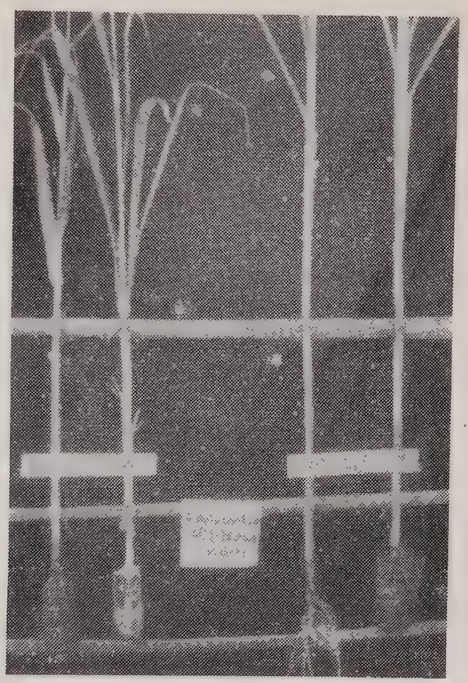


Fig. 2. Rooting of canes by alkathene bags and tile pots.

The new method dispenses with the cumbersome procedure of tying two halves of the tile pot together and keeping it in position round the cane. The Alkathene rooting bags could be put up at the top nodes without needing any support, and the rooting was not only quicker, but the percentage of root eyes sprouted at that level of the cane was also high. By such ' high level ' rooting the cane when isolated could be ' midgeted ' to a convenient height of 3′ to 4′ for crossing purposes (Fig. 3). The ease of handling arrows for controlled breeding work, rendered by the new method, would be appreciated when it is considered that sometimes a cane in arrow is of such great height, that even the tallest ladder is not able to reach it and a special ' Pollen stick ' had to be used as shown in Fig 4.

The greatest benefit derived from the new technique, was that Alkathene very effectively preserved the moisture in the medium. When once the Alkathene bag was put round the cane filled with moist soil, there was no need to water for a second time at all. Further, the plastic film being transparent, the formation of roots could be watched to decide the stage and time for cutting the rooted cane.

Mass isolations by this method were tried with cent percent success. It was seen that the canes could be rooted even at the tip emergence stage of the arrow, and the same isolated in time for controlled crossing.

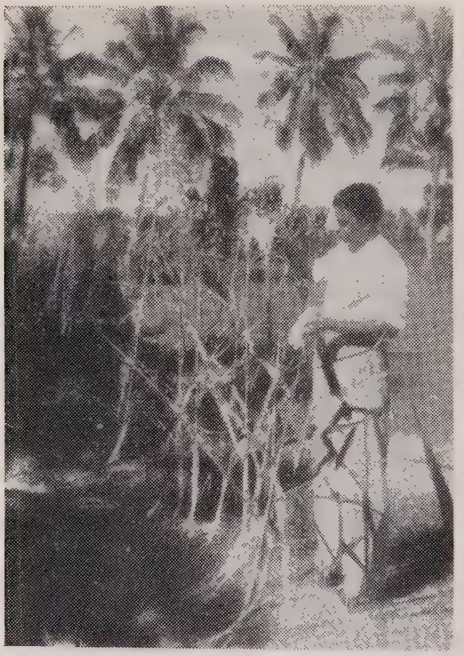


Fig. 3. Isolated arrows available at a convenient height for hybridisation.

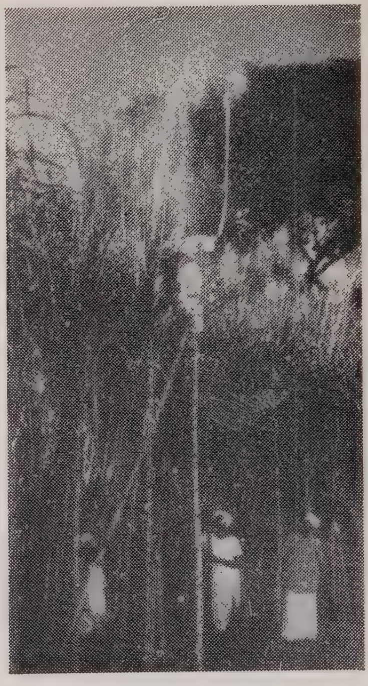


Fig. 4. Technique of hybridisation with the special ' pollen stick. '

TRAYON* BAGS

Previously muslin bags used to be employed for controlled crossing and for safeguarding the crossed arrow from foreign pollen. Recently special trayon paper bags fitted over thin bamboo strip cages have been used as shown in Figs. 5 and 6. The trayon bags are quite strong and do not tear easily. The other advantage is that they are transparent and allow light to pass through. The occurrence of moisture, high humidity, temperature, fungal growth and the consequent poor seed setting which were invariably associated with the use of cloth and other paper bags were noticeably absent in the case of trayon bags.

SOWING OF SEED IN FLATS

A few modifications have now been made in the method of sowing of sugarcane seed. Previously the seed used to be sown in the Sowing Shed and the seed pans were then removed to the bamboo platforms. The platforms are now of cement slabs and therefore absolutely of a uniform level. The seed pans are kept arranged on the platform and are not removed to the Sowing Shed for sowing and then brought again to the platform. Separate cement rings are provided which fit just above the seed pan and each individual pan is sown. The cement ring prevents the blowing of seed from one pan to another by the wind. In former years country made earthenware seed pans were used. A few years later these were replaced by glazed pans and still later by cement pans. It has now been found that if brick walled flats are made on the cement platforms, the seed germinations and the health and vigour of the seedlings are better than when they are raised in earthenware pans, or glazed pans or cement pans or cement concrete flats. The bricks have to be changed every year. The success is perhaps due to the porous nature of the fresh bricks which allow aeration and drainage of water.

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*Trayon is a cellophane type paper manufactured by Travancore Rayons Ltd., Trivandrum.

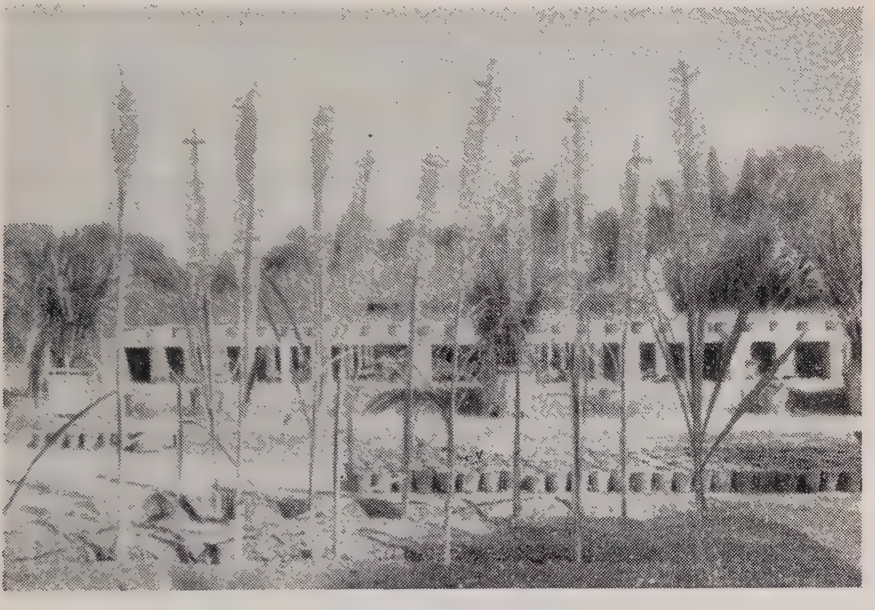

Fig. 5. Trayon cages on isolated canes.

ELIMINATION OF FIRST GROUND NURSERY

As per the old method, seedlings germinating in seed pans ($1\frac{1}{2}$ months old) were transplanted in the field in what was known as the first ground nursery. After 3 months, vigorous seedlings used to be uprooted, leaves trimmed, tops cut and transplanted into the second ground nursery. It was felt that two transplantings within a short period of 5 months acted as a set back and affected the growth of the seedlings. The first ground nursery has now been eliminated. Seedlings from the seed pans when they were about 6″ high, were transplanted individually into the tile pots. There they grew for a month and when the seedlings began to tiller, i.e., when the'B' shoot began to emerge, they were ready for transplanting into the field. The seedlings were removed from the pots with the root system and soil intact and transferred to previously prepared pits, 2′ apart in the field. It was found that barring 1½ monhts in seed pans and 1 month in tile pots, the seedlings remained for full 12 months in the field nursery enabling proper evaluation of their characteristics and selection by next February. Moreover, the intrinsic value of first year characters like tillering, growth vigour, habit, etc., could be properly assessed as the seedlings were allowed to enjoy continuous growth without disturbance at any stage.

Fig. 6. Sugarcane arrows in the field covered with trayon cages.

The growth vigour as compared to the seedlings transplanted by the old method is shown in Figs. 7 and 8. The tilllering was far more satisfactory and the height and girth of individual stalks was also much better. Immediate advantage was taken of this availability of large amount of planting material at the seedling stage itself. Half the material in the selected seedling was planted at Coimbatore and the other half sent to the Institute's sub-station at Karnal to test their performance under sub-tropical conditions where the bulk of the cane area in India even now lies.

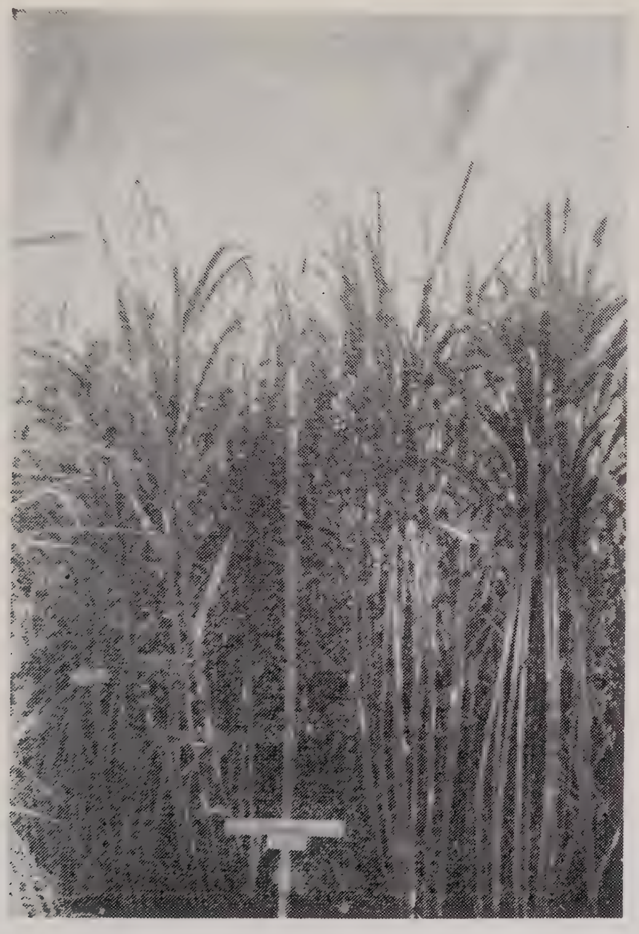

Fig. 7. Seedlings transplanted from pots.

It may be mentioned in passing that potting seedlings in the early stages is practised in other countries as well (Mangelsdorf, 1953) though not with the same ends in view as ours. For us, getting sufficient planting material for simultaneous testing and selection of suitable commercial canes for both the subtropics and tropics was the main objective.

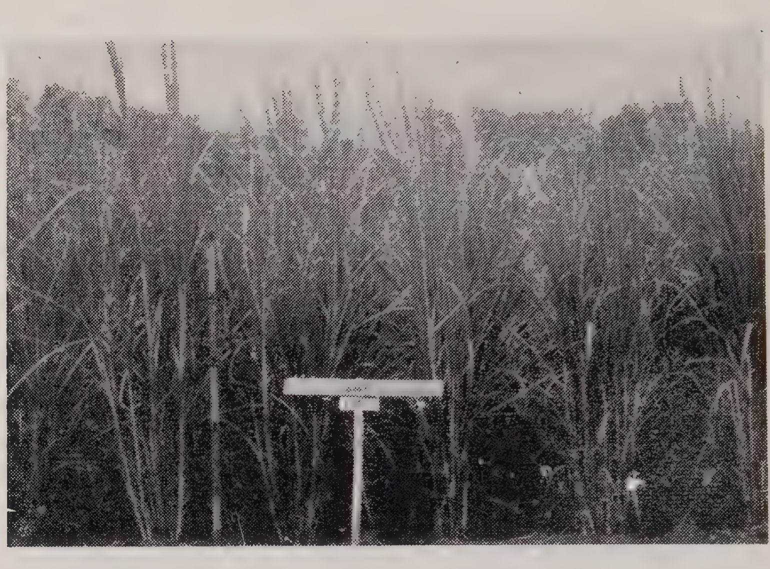

Fig. 8. Seedlings transplanted from first ground nursery.

The growth of the seedlings in the new method was much better as compared to the old method. The tillering was far more satisfactory and the height of the canes was also good. Immediate advantage was taken of this availability of sufficient planting material.

RAPID PROPAGATION AT THE YOUNG SEEDLING STAGE ITSELF

Mainly with a view to saving planting material of available seedlings from the attack of mosaic, the technique of multiplying the material available from

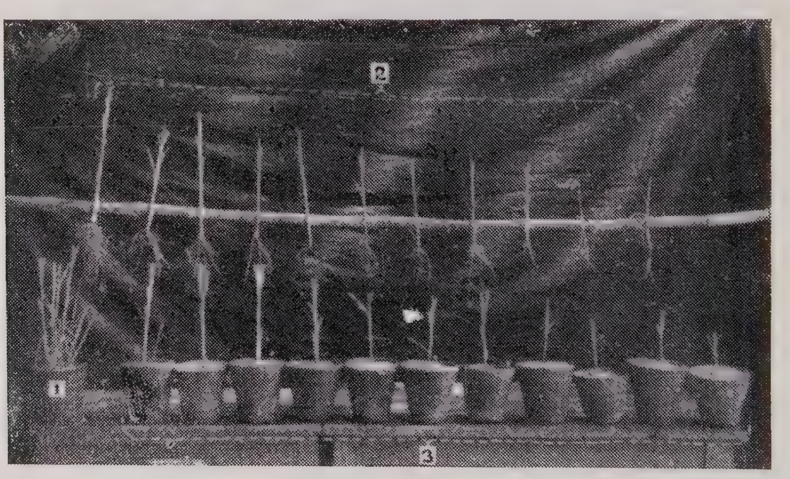

Fig. 9. 1. A seedling in pot with 11 tillers. 2. Tillers separated showing roots. 3. Individual tillers planted in tile pots.

seedlings at the younger stage itself has been evolved. There is a secondary spread of mosaic at Coimbatore and unfortunately some of the best seedlings had to be removed and destroyed because of the attack of mosaic. The device now used in about 20% of the total number of seedlings is that when the seedlings have to be transferred to the field from the tile pots, each seedling has been separated into the available tillers with their individual roots and planted as separate units. It was noticed that even if the mosaic attacked 60 to 70% of these canes, at least 30 to 40% were still available and thus the seedling was not completely lost to the Station. Incidentally this method came in very handy for obtaining large amount of planting material from the seedlings (vide Figs. 9 and 10). This enabled the testing of planting material at the earliest available

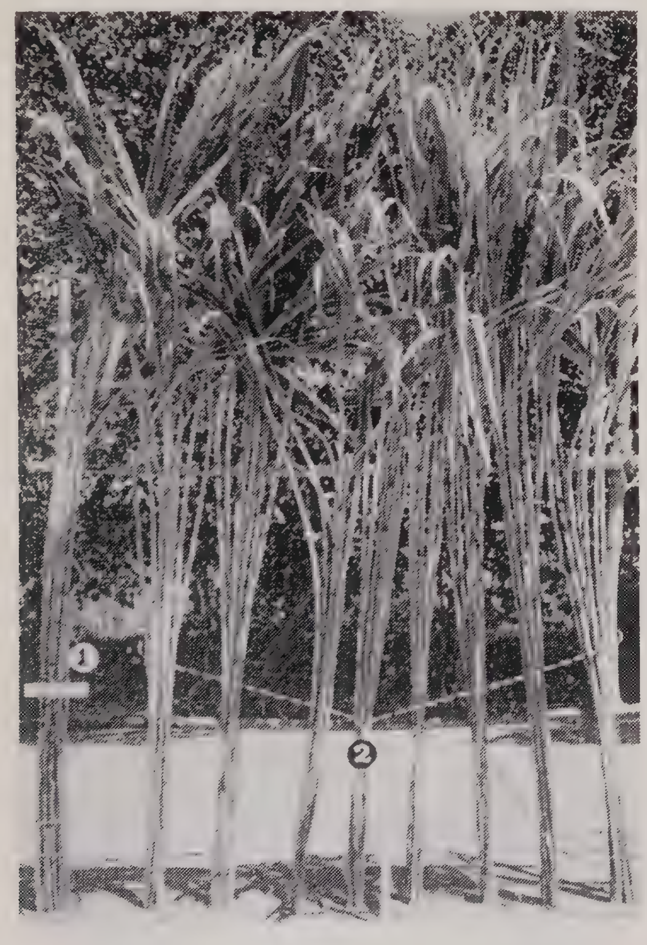

Fig. 10. 1. Planting material available from a single seedling.
2. Planting material available by the method of tillers separation.

stage simultaneously at Karnal and at Coimbatore, that is to say, both under the sub-tropical and tropical conditions.

The tiller separation method described above agrees in principle with the 'Seblang' method developed in Java (Dillewijn, 1950) for rapid propagation of sett planted material. But this is apparently the first case where promising new varieties raised from seed are subjected to this tiller separation treatment and their worth and usefulness as commercial types assessed very early.

DESPATCH OF SEEDLINGS BY AIR

The testing of the seedling canes from the ground nursery stage at the Sugarcane Sub-Station, Karnal, has been mentioned above. The existence of air mail service has helped in carrying the seedlings themselves. Previously the best that could be done was to send seedlings by train all the 1,800 miles. The seedlings had to be trimmed and kept watered during the long journey of nearly five days. Now 1½ month old seedlings from flats are taken with the adhering soil and wrapped in moist coconut fibre. An eight pound parcel contains 2,400 seedlings and reaches Karnal the next day. Figures 11 and 12 illustrate the way seedlings are packed and sent.

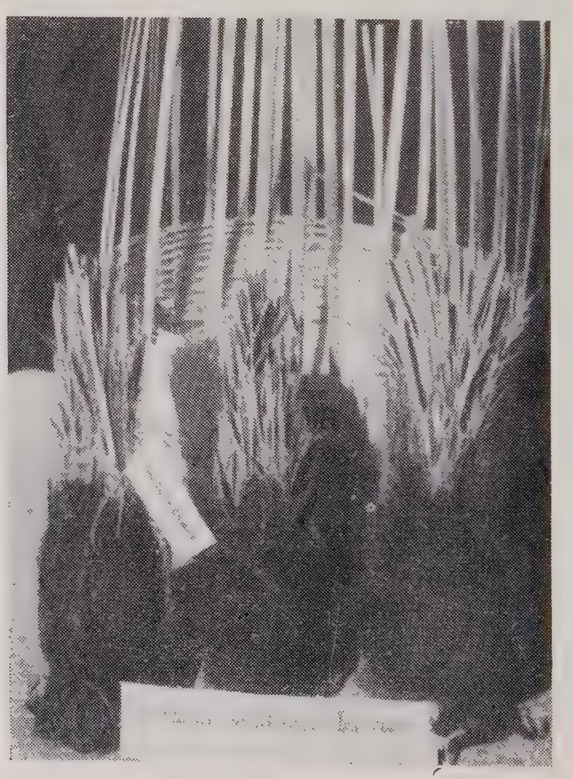

Fig. 11. Seedlings packed in coconut fibre for air parcel.

USE OF ALKATHENE IN CANE PARCELS

The use of Alkathene for isolating live canes has been described in section above. Alkathene has come in handy in yet another important way. The old method of packing cane for foreign despatch was to use moist charcoal as the packing medium (Venkatraman 1920). This has been replaced altogether by enclosing the canes in Alkathene tubes. The cane material has remained fresh upto 1½ months in Alkathene tubes and 80% of the buds were quite fresh and healthy.

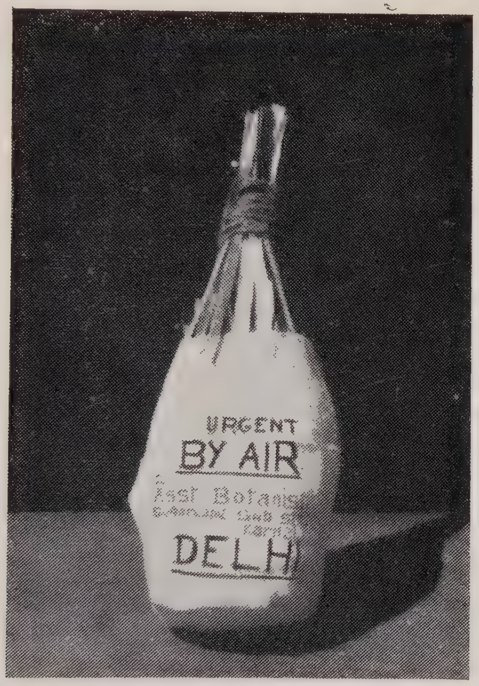

Fig. 12. Seedlings ready for despatch by air.

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Dr. H. M. Tysdal then presented his paper.

Paper

PROMISING NEW PROCEDURES IN SUGARCANE BREEDING

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The excellent progress which has been made over the years in sugarcane breeding speaks for itself. Methods used must have been worthwhile, else such progress could not have been made. The very excellent discussions on sugarcane breeding by Warner (14) and Stevenson (11) are commended to your attention. It is therefore with some hesitancy that I address this group, but I am sure you are all of the same opinion ; namely, that as new tools and new methods are developed, the greatest possible use should be made of them. In this discussion, therefore, I will touch on a number of possible new tools, not to overlook the use of old ones.

The first procedure I would like to discuss is that of "recurrent selection." This term was first proposed by Hull (6), but the method has been studied by Sprague (10) and Lonnquist (8) in corn, and by El Banna and Johnson (3) in sweet clover. In 1949 Comstock, Robinson and Harvey suggested a procedure to make maximum use of both general and specific combining abilities (2). This they called reciprocal recurrent selection ; and since it embodied procedures of recurrent selection together with an additional feature of using two different sources of material, this method will be described. Figure 1 gives a diagram of the steps involved in a reciprocal recurrent selection programme. It should be pointed out that the first essential is to obtain highly desirable sources of material. It cannot be hoped to obtain anything out of a breeding programme that is not in the material in some form or other in the first place. Therefore, the selection of the source clones should be made with great care and much research. In the suggested outline, which is used only as an example of what might be done in a reciprocal recurrent selection programme and which can be modified to suit local conditions, Source A is considered as a group of highly selected, highly desirable disease-resistant sugarcane clones, unusually high in sugar content. Source B is composed of a group of sugarcane clones which are vigorous, highly disease-resistant, and are desirable in as many characters as possible, but perhaps not quite as high in sugar content as would be desired. Starting out with these two highly selected sources, the first year clones in Source A are cross-pollinated

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It is a pleasure for the author to acknowledge constructive reviews of the manuscript by I. B. Stokes and Carl Grassl.

RECIPROCAL RECURRENT SELECTION

	Source A	*Source B*
(1)	Highest sugar clones crossed with B clones as pollinators	Vigorous clones crossed with A clones as pollinators
(2)	Field test progenies from each maternal parent Select individuals for possible commercial varieties	
(3)	Intercross best clones of A based on results in (2)	Intercross best clones of B based on results in (2)
(4)	Field test progenies, select superior, highest sugar clones also commercial possibilities	Field test progenies, select superior, highest vigour clones also commercial possibilities
	Source A^1	*Source B^1*
(5)	Highest sugar clones crossed with B^1 clones as pollinators	Vigorous clones crossed with A^1 clones as pollinators

Repeat as in (2), etc.

Fig. 1. Example of a procedure for a reciprocal recurrent selection programme in sugarcane.

using clones of Source B as the pollinators. Similarly, the clones of Source B are crossed, using A clones as pollinators. It should be stressed that a recurrent selection programme as the entire breeding programme to the exclusion of other methods of breeding is not proposed. Other methods also have their places.

There may be several ways of making these " top crosses," but it should be remembered that in order to carry out the purposes of the method it is desirable to have a rather complete representation of all the clones of the source used as the pollinators in order to get an evaluation of the combining ability of the one group of clones with the other.

The question of the need for making reciprocal crosses is also of importance. In general, while it is believed that in sugarcane reciprocal crosses may differ because of possible differences in development of the male and female gametes during meiosis, nevertheless, due to the difficulty of making and testing a large number of crosses, it is here assumed that making reciprocal crosses would not be necessary. One way, therefore, of determining the breeding behaviour of the clones is to intercross them in all combinations. Assume, for example, there are 20 clones of each source (it would be desirable to have more if possible), it is probable that each clone could be crossed with every other clone in the opposite source ; that is, clone 1 of Source A would pollinate or be pollinated by each clone in Source B, making 20 crosses for each clone, or a total of 400 crosses altogether. Since it would probably be as easy to keep the crosses separate as to composite them, they could be planted in this way, but the evaluation of the combining ability of each clone of one source with those of the other would be determined by the sum total of all the twenty crosses. If it is possible to have more than 20 highly selected clones in each source, say for example, 100, then since it would be impossible to make all crosses it would be necessary to select perhaps five of the best clones with high pollen fertility from each source to use as pollinators on all of the clones of the opposite source. In this way, there would be 500 crosses from each source or a total of 1,000 crosses. The combining ability and breeding behaviour of each clone would then be based on the average of five crosses which might afford a fairly good basis of evaluation and, at the same time, may provide desirable material for selection.

It is recognized that there may be difficulties in obtaining viable pollen from all clones or synchronization of time of flowering. However, if the cross can be made either way and through the manipulation of temperatures (elevation or greenhouse), daylength, nutrition, and by chemical treatment such as maleic hydrazide to delay flowering, most of the desired crosses undoubtedly could be made.

In any event, these crosses should provide at least two things : (1) an evaluation of the combining ability of the female clone with the clones of the opposite source and (2) they should provide material for possible commercial varieties since they are crosses between highly selected clones.

The second step in the programme is to make a field test of the progenies from each female clone. This is carried through in the usual manner, obtaining the results as soon as possible. It is in this test that individuals might be selected for possible commercial use. Thus, in this respect the procedure might be considered the same as in a normal breeding programme.

Perhaps the chief departure from the usual breeding programme is described under Step (3), Figure 1, in which a return is made to the original clones for intercrossing those which have been found to have the best breeding potentialities, instead of proceeding with advanced clones, which, however, may contain deleterious genes from a poor parent. This third step involves an essential in a reciprocal recurrent selection programme because it provides the opportunity of intensifying the desirable high-combining genes found in each source. Thus, the best clones found by a progeny test in Source A are recombined or intercrossed among themselves to provide seed for the next generation of selection. Similarly the best clones found by the progeny test from the group in Source B are intercrossed to give seed which then enters the next recurring cycle of selection which is represented in No. 4 of Figure 1. This particular phase of the cycle allows concentration of, for example, genes of a higher sugar content in source A based upon the known breeding behaviour of each clone.

The seed obtained from intercrossing among the best clones in Source A and source B as outlined above is planted in the field, and individual plant selections are made from each of these groups, keeping the groups separate, to form the basis of a new recurrent series of selection. Among the intercrosses from Source A special attention would be given to those high in sugar content, but they should also be highly desirable from every other possible characteristic such as disease resistance, vigour, etc. Similarly, from the intercrosses of Source B the highly vigorous, highly disease-resistant clones would be selected. Moreover, some of the best of these should be studied for possible commercial use. Procedure No. 1 or 5 (Fig. 1) would then be repeated by pollinating Source A^1 with Source B^1 and vice versa. As can be seen, this step involves intercrossing clones highly selected for both their desirable characteristics and their basic combining ability with the opposite source. This again should provide valuable material for possible commercial use. By this time the breeder is in the second cycle of the reciprocal recurrent selection programme, and the procedure is repeated as shown in Figure 1. The procedure does not preclude the possibility of adding new source clones at any time.

Recurrent selection differs from the reciprocal recurrent selection outlined above simply by having only one source instead of two, and the procedure for carrying out a recurrent selection programme for combining ability would be the same as outlined for one of the sources in Figure 1, using a common pollinator or random pollination within the one source. The latter method or, as it is sometimes called, the polycross method, has been used by Stewart and Coe (unpublished data) with considerable success in sugar beets. If combining ability is not a factor in the selection programme as, in the case of sweet clover where the final commercial variety would not be a hybrid, the progeny test for combining ability can be omitted ; thus, the plants selected for the desired characters can be immediately intercrossed, greatly speeding up the programme. In the case of sugarcane it would seem highly desirable to include a study of combining ability or breeding potentiality in the programme.

Most of the workers who have reported on recurrent selection in corn have reported favourably on the method. Sprague and Brimhall (10), selecting for high oil content in corn, state : " The recurrent selection procedure, at the end of a 5-year period, was 2.6 times more efficient than selection during inbreeding under the conditions of this experiment." Lonnquist (8), selecting for combining ability in corn, states "The method appears to provide greater efficiency in the selection of superior genotypes as well as a higher level of combining ability in the lines obtained." It must be stated, however, that the method has not been fully tested, particularly with respect to such factors as yield itself. Undoubtedly, when selecting for characters with relatively high heritability, the method is successful. The genetic variance is also maintained to a considerable extent which is advantageous for selection. Thus, the method appears to have a number of advantages which might prove useful in sugarcane breeding. It provides a consistent, systematized procedure which can be carried out over a period of years while at the same time allowing for the production of possible commercial clones at many stages of the programme.

Another phase of great interest to the plant breeder is the " selection significance " of the characters with which he is dealing. In any breeding programme it is desirable to know as much as possible regarding the inheritance of economic characters and their bearing on the selection programme. It is a pleasure to report some recent results obtained by L. P. Hebert (5), who has been studying the correlation between certain characters of the sugarcane at an early stage of selection compared to the behaviour of the same clone after multiplication and in field tests at a later date. Such studies may give us a clue as to the reliability of early selection for given characters. In one study, for example, Hebert compared the stalk diameter of a seedling (from true seed) single stool in the first stubble grown in 1953 with the stalk diameter of the same clone vegetatively increased and planted in multiple plant plots grown in 1954. Using a population of 896, he found a correlation of 0.635 between the stalk diameter of the seedling and the vegetatively propagated progeny in the multiple plant plot. Similarly, using the same population, the correlation between the Brix of the first stubble of the single stool compared with that of the plant cane in the following year was 0.587. In the same study, the correlation between erectness of stalk of the seedling with that of the multiple plant plot was only 0.332 and that of number of stalks per stool in the two populations was 0.288. Such results, when substantiated with different populations and under different seasonal conditions, could be tremendous assistance by indicating to the plant breeder the characters for which early selection could be practised. In this case, considering the variability of the environment, there appears to be a correlation of " selection significance " in the characters Brix and diameter of stalk, but in the case of erectness of stalk and number of stalks per stool in this population at least the selection significance of the correlations appears to be very low. Hebert states that crossing two low-Brix varieties gave progenies of relatively low quality juice. No progeny gave juice as high in Brix as the calculated value indicated for the higher of the two low-Brix parents. Two crosses involving high-Brix parents gave relatively high numbers of seedlings with juice of higher Brix than either of the high-Brix parents. In addition, crossing a high-Brix with a low-Brix parent gave a high percentage of individuals with high-Brix juice and relatively few with juice of low-Brix.

In studies of correlation of characters within the same plant, Stokes (12) and Hebert (5) report relatively low coefficients. For example, Hebert found the following correlation coefficients when comparing measurements made on each plant of the first stubble of single stools in 1953: stalk diameter and Brix,0 .012; stalk diameter and erectness, 0.010 ; stalk diameter and number of stalks, 0.039; Brix and erectness, 0.100 ; Brix and number of stalks, 0.040 ; and erectness and number of stalks, 0.243. Similar studies on plant cane in 1954 produced essentially the same results. Stokes (12) reports coefficients of about the same magnitude with the exception of a correlation of 0.566 between stalk weight and stalk diameter. Thus, it appears evident that, although among these characters there are none which can be used as a basis for the selection of other characters, nevertheless it is helpful to know that there apparently are no linkage groups blocking the way to progress. For example, selection for high Brix can go forward while at the same time selecting for other desirable characters.

One of the useful techniques in sugarcane breeding is that of marcotting. As an innovation in marcotting, the use of polyethylene is illustrated in Figure 2. This has been an adaptation by Carl Grassl. Marcotting is not a new procedure. In fact, Venkatraman of India suggested this system many years ago. It is noted, however, that with the pliofilm and the use of sphagnum moss, large numbers of cane can be marcotted at relatively low expense.

A discussion of breeding techniques would be remiss if the important roles of cytology and cytogenetics were omitted. Through such studies the cytologic behaviour of the plants can be obtained, thus shedding light on better methods and procedures for further breeding. Space does not permit a review of the important findings already reported in this field.

There has been a recent renewal of interest in the use of ionizing radiations in plant breeding. Here again the field is not new because Gustafson and other Swedish workers, Stadler in the U.S.A., workers here in India, and others have reported many mutations in plants induced by X-rays. With the present availability, however, of both gamma ray and neutron irradiation, interest has greatly accelerated. One of the most interesting possibilities emerging from some of the studies on irradiation is the use of this technique on a large scale to provide

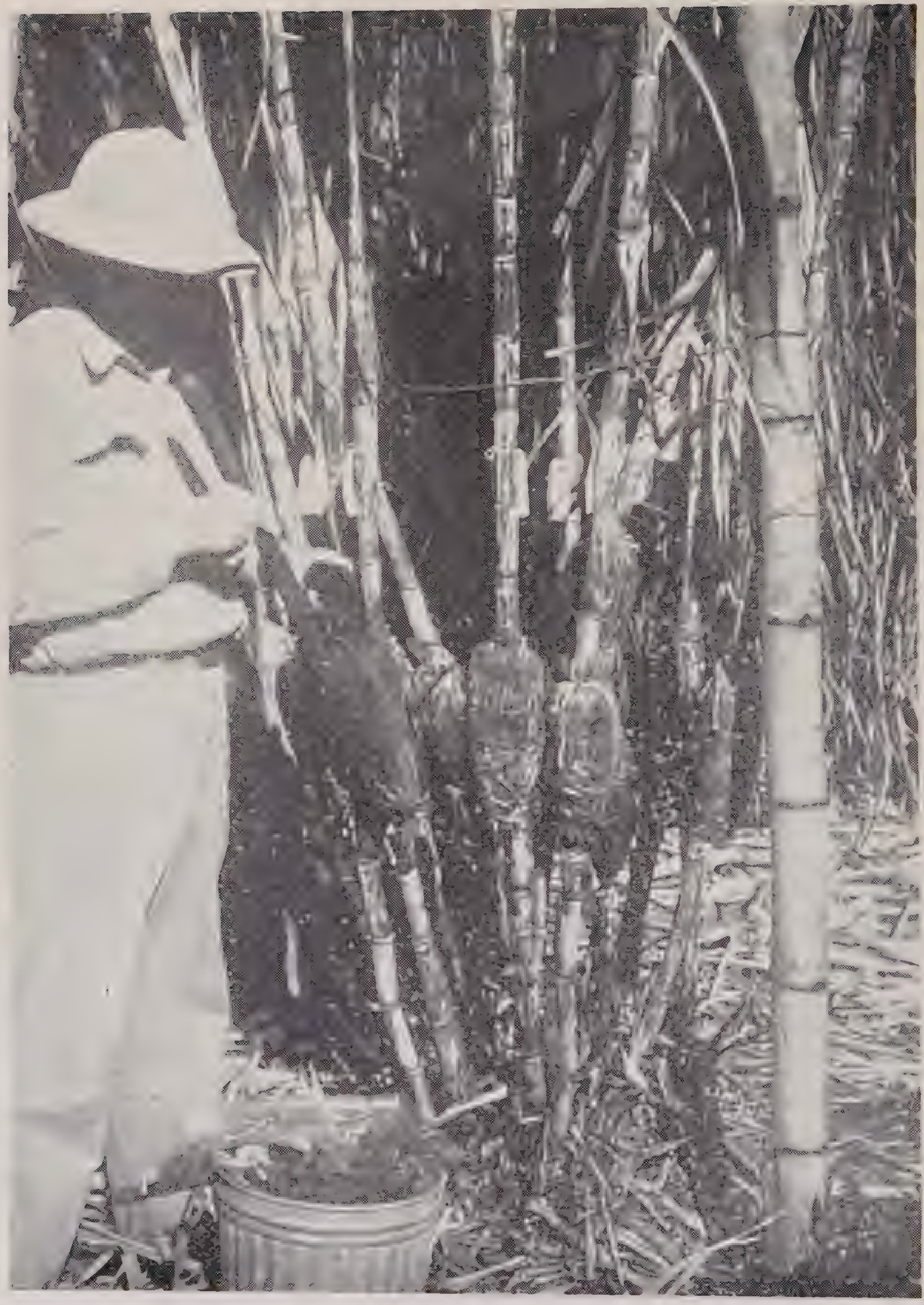

Fig. 2. Marcotting or air-layering cane using sphagnum moss and polyethylene. Carl Grassl is shown packing the moss in the photilm container before tieing the top. Note the roots formed in the moss on the adjacent stalk after only three weeks.

germplasm for a breeding programme. Startling results have been obtained by irradiating wheat, peanuts, oats, and other plants with either gamma rays or neutrons to provide new segregates or new combinations of germplasm for better types or for disease resistance. Some of these results are reported by Singleton (9). Ausemus and his associates (1), working at Minnesota and co-operating with the Brookhaven National Laboratory, reported at the 1955 Agronomy Meetings that irradiation of Lee wheat produced segregates which are resistant to the stem rust Race 15B to which Lee itself is very susceptible. This strain of rust has raised havoc in the spring wheat areas of the United States and Canada over the past several years, and resistance to this race has been difficult to obtain. Yet, in one stroke such resistance was obtained without apparently changing the nature of the variety itself. Similarly, in oats, Konzak (7) found segregates resistant to *Helminthosporium victoriae* blight through irradiation. In peanuts, Gregory (4) found that after irradiating several bushels of seed, some of the resulting segregates were much superior in yield to the original variety, and he also obtained a leaf-spot-resistant segregate. He states : " The total genetic variance among the randomly chosen irradiated normals was four times that measured in control progenies. Several high-yielding mutants were recovered from the populations studied." It is believed, therefore, that this procedure offers an opportunity for sugarcane breeders. A small start has been made on the irradiation of sugarcane seed pieces with the hope that desirable segregates could be obtained, possibly with higher yielding ability, higher sugar content, and greater disease-resistance. Figures 3, 4, and 5 illustrate how this has influenced the growth of the cane.

Seed pieces were irradiated in the Brookhaven National Laboratory through the co-operation of Dr. Seymour Shapiro. The material was supplied and planting supervised by Dr. I. B. Stokes. The sugarcane seed pieces were exposed to neutron radiation for 2, 4, 6, 8 and 10 hours. The 8- and 10-hour dosages were too severe as shown to the right of Figure 3. Similarly, seed pieces were exposed to 2,000, 4,000, 6,000, 8,000 and 10,000 roentgens of gamma radiation. As shown in Figure 4, the buds exposed to 4,000 r were either killed or seriously injured, or produced dwarfed plants, and those exposed to over 4,000 r were all killed. Mutations were observed in many of the surviving plants of both radiation treatments. Figure 5 shows two such mutations, one stalk having a brown stripe limited to one internode, the other showing both normal and extremely shortened internodes. These are only the more obvious types of mutations observed. High irradiations have greatly stunted the growth of the plants. The effects of irradiations on the growth of sugarcane plants apparently vary with varieties. Presumably, it would be desirable to use the less severe dosages, testing the plants carefully for any gene mutations. Cane is now being irradiated which is infected with the mosaic virus disease and others that are infected with the ratoon stunting disease to determine if it is possible to eliminate the virus disease from the plant without harmful results to the plant itself or to induce mutations in the plant making it resistant to the diseases. Results have not yet been obtained.

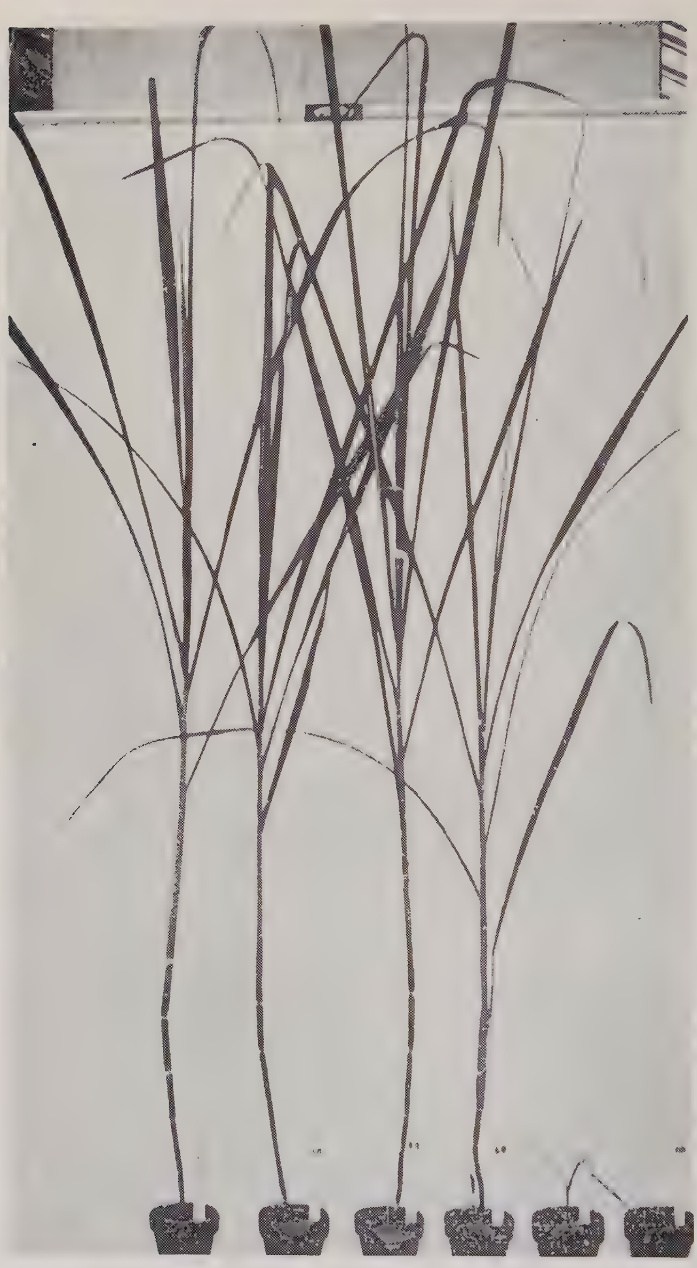

Fig. 3. Cane grown from seed pieces which had been exposed to neutron radiation at the Brookhaven National Laboratory. Left to right, 0, 2, 4, 6, 8, and 10 hours exposure.

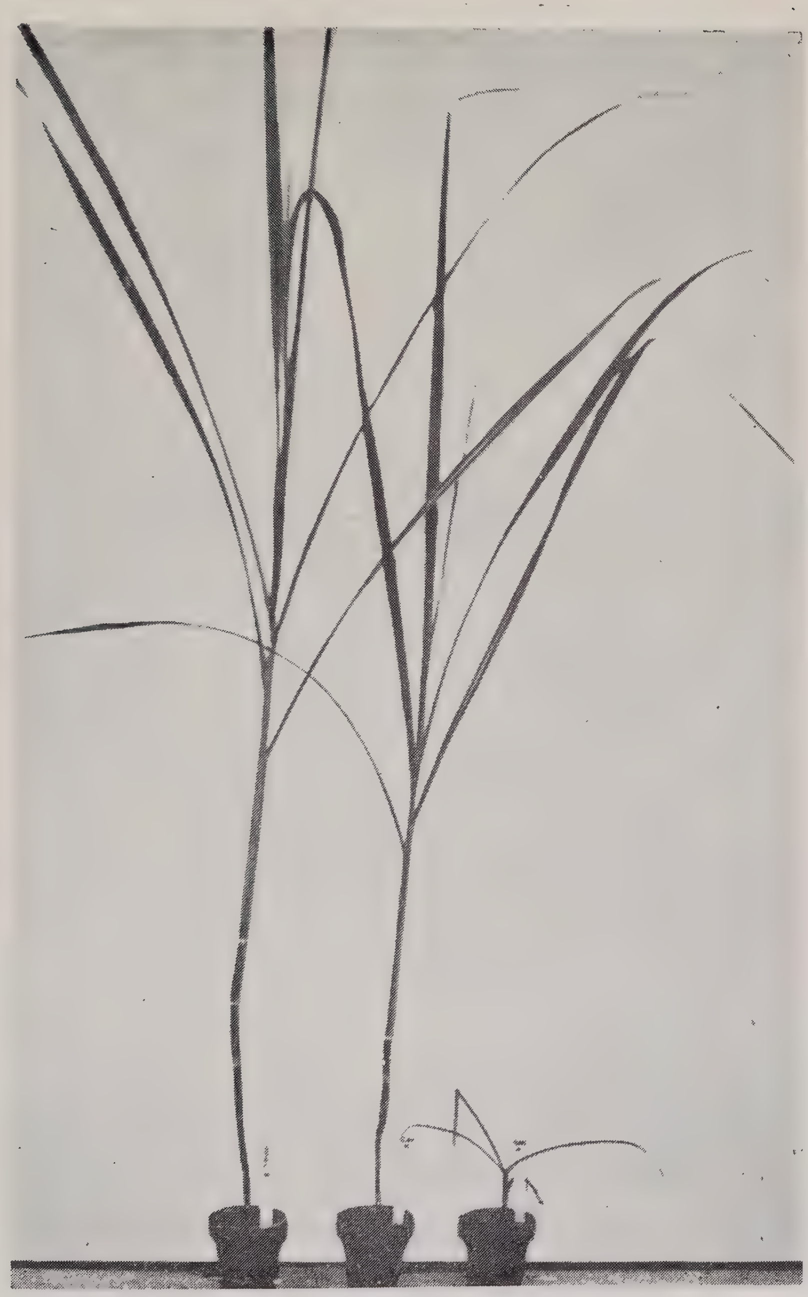

Fig. 4. Cane grown from seed pieces which had been exposed to gamma radiation. Left to right, 0, 2,000, and 4,000 r.

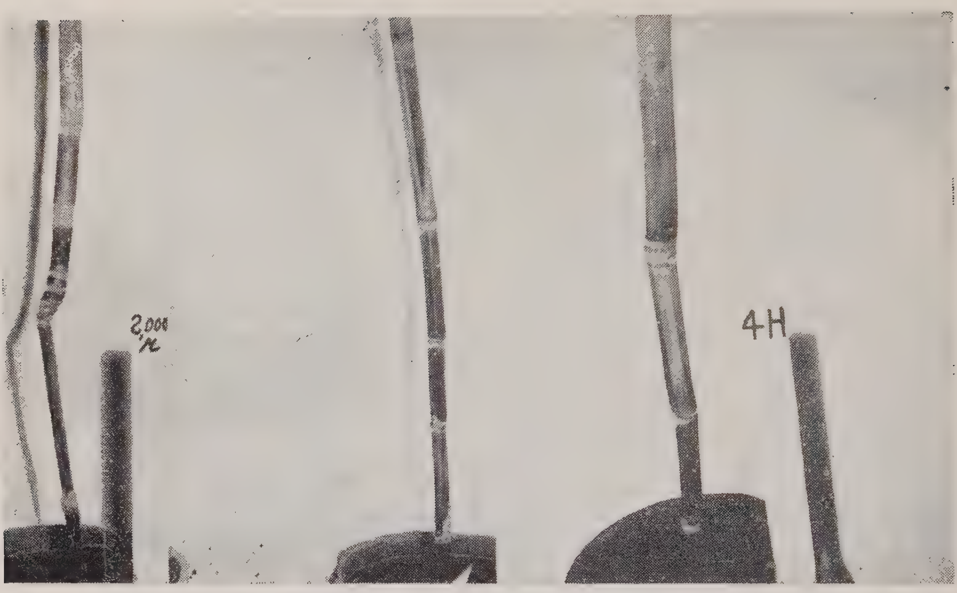

Fig. 5. Mutations caused by radiation. Note the shortened internodes on plant on left and the narrow stripe on the third internode of the middle plant, both of which were exposed to 2,000 r. The plant on the right having a stripe on one internode only was exposed to 4 hours neutron radiation.

In speaking of new germplasm, the possibility of intergeneric and interspecific crosses as a source of new combinations must not be overlooked. We, as you in India with your collection of wild canes, and others, are doing a considerable amount of work on crossing species in order to obtain certain characters of value in the breeding and commercial programme. Recently Todd (13) under the conditions at Canal Point, Florida, has found apparent resistance to the ratoon stunting disease in several clones that are quite desirable as sugar producers. In preliminary tests it appears that B. 39246, Ba. 11569, Cl.41-70, and C.P. 1 may have considerable resistance to the disease. This perhaps minimizes the necessity of using species crosses to obtain resistance to this disease. However, there are many characters of the various sugarcane genera and species which would be desirable to incorporate in the commercial types. It would seem worthwhile, therefore, to sort through the gene complexes of various species to determine what each might contribute to a final desirable commercial variety.

Recently an attempt has been made to see if the ratoon stunting disease could be studied or detected by means of tracer techniques, using P32. In one instance a considerable difference in uptake was found, as illustrated by the radioautograph shown in Figure 6. Stalks of diseased and healthy shoots of comparable size were cut under water and then the cut end immersed in a solution containing 250 millicuries of P32 per liter of water. After 110 minutes the geiger counter reading

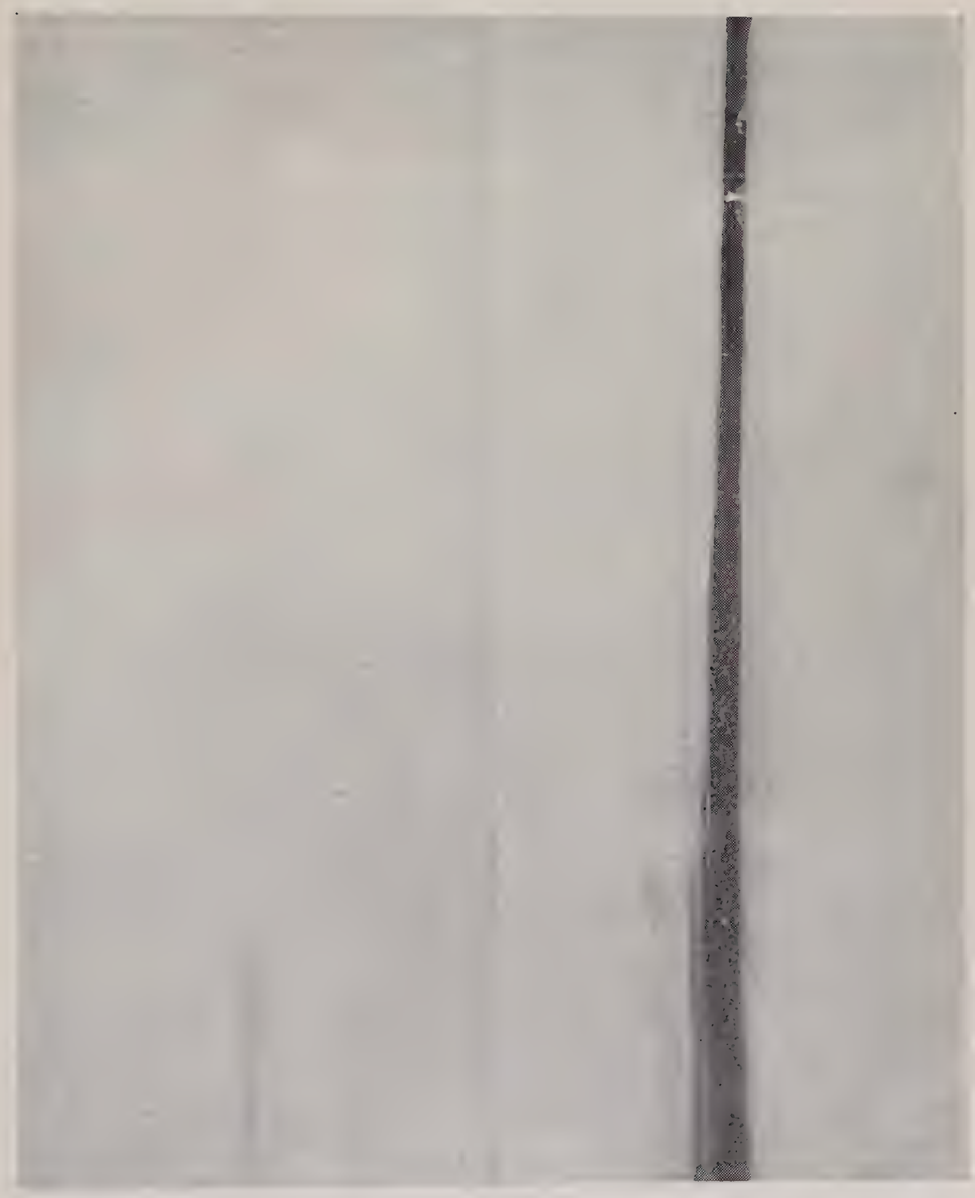

Fig. 6. Radioautograph of two sugarcane leaves. The one on right was from a healthy plant whose stalk was immersed in a solution containing 250 millicuries of P32 per liter, while the leaf on the left was from a plant infected with the ratoon stunting disease treated in the same manner—photographed after 110 minutes in the solution. Note the greater uptake of P32 in the healthy plant, shown by the dark midrib.

on a leaf of the healthy plant was considerably higher than that from a comparable leaf of the ratoon stunting diseased plant. These data are very preliminary and are mentioned only to indicate the possibility that further studies may indicate whether there is plugging of the vessels, where this occurs, and perhaps other valuable information. This study was carried out by Dr. Stokes of our Section in cooperation with Drs. Cecil H. Wadleigh and C. H. Hagan of the Soil and Water Conservation Research Branch.

Despite new methods and new tools by which we may attain progress, it must be admitted that in the long run it requires painstaking work, carried out on a relatively large population using the best screening methods for diseases and other characteristics to provide the progress which is essential to maintain a vigorous, economic, profitable industry. We need only point to the fact that breeding and selection saved the sugarcane industry in Louisiana, which was being devastated by the mosaic disease, in order to show the importance of research programmes. I am sure there are similar examples in practically every country. It is through meetings such as this that maximum progress can be made under the auspices of a co-operative programme supported by the sugarcane research workers and industry of all the world.

SUMMARY

The reciprocal recurrent selection procedure is outlined and its application to sugarcane breeding is illustrated. While most of the principles involved are not new, it may find a place in sugarcane breeding in order to provide a consistent, systematized procedure which can be carried out over a period of years while at the same time allowing for the production of possible commercial clones at many stages of the programme.

The need for studies on the " selection significance" of characters in sugarcane is stressed. Reports of correlation between such characters as stalk diameter and sucrose content, brix and number of stalks, and others are given. Most correlations are low, but some have significance in a breeding programme. In addition, the reliability of early selection for given characters is noted.

A discussion of the value of ionizing radiations in plant breeding is given, showing the striking results in obtaining disease-resistance in cereals and desirable mutations in peanuts. Its possible application to sugarcane is indicated together with illustrations of sugarcane seed pieces exposed to both gamma radiation and neutron radiation. The work having been started very recently, results on sugarcane are not yet available.

The use of tracer techniques in studying diseases, particularly the ratoon stunting disease, is reported upon. Preliminary studies indicate the possibility of gaining information regarding plugging of the vessels of behaviour of the disease through this technique.

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In the absence of the author the following paper was presented by Mr. C. Mazery.

Paper

RECENT DEVELOPMENTS IN SUGARCANE BREEDING IN MAURITIUS

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Mauritius Sugar Industry Research Institute, Mauritius

BREEDING POLICY AND METHODS

Major objectives in the breeding and selection programme are the production of :—

1. A range of varieties possessing desirable agronomic features combined with high sucrose content and high juice purity.
2. Early maturing varieties.
3. Canes adapted to sub-normal environment.

BREEDING OF HIGH SUCROSE CANES

Combining high sugar and vegetative vigour in one clone is a problem of the highest economic importance. It would appear that, in the light of results obtained at cane breeding stations the world over, the blending of high yielding capacity and sweetness is in general difficult to achieve by straight crosses but should be carried out by a process of back crossing.

The fact that success has been obtained with other crop plants with the back cross technique, has recently prompted the consideration by the Sugar Industry Research Institute of this method as an adjunct to the general breeding methods of evolving high sugar yielders.

Briggs and Allard (1) report the success achieved in California in back crossing programmes with numerous crops. The steps taken to transfer stem rust resistance from the wheat variety Hope to the bunt resistant variety Baart are cited to illustrate the technique used. Other examples concerning cereals, flax and Lima bean, show that back crossing can effectively improve a variety, with respect to both qualitative and quantitative characters.

Naturally a programme of repeated back crossing is beset with difficulties. There is, in the first place, the time-consuming factor of preserving a definite character in successive generations by selection. Data obtained for several crop plants indicate that a varying number of generations of intercrossing parent varieties is necessary in concentrating desired genes in the offspring. In sugar cane, the process will probably be long owing to its highly heterozygous make-up.

Owing to environmental variability the desired genotypes may be difficult to identify. They may also occur in such low frequencies that large seedling populations may be necessary to provide reasonable odds that the genotypes may be present. In addition to these, there is the possibility that undesirable genes, closely linked with the genes to be transferred from one parent variety to the other, cannot be purged. Last, but not least, there is the difficulty that interesting individuals from a cross may not flower, or if they flower, they may not arrow at the appropriate time and they may not be of the proper sex.

Some back crossing has been carried out at the Sugarcane Research Station during the period 1940-47 but not in a systematic manner. Derivatives of M. 134/32 were mated to the mother itself or to P.O.J. 2878, the grand parent, with unpromising results. The work was resumed in 1954 by crossing offspring of several crosses with one of the parents, the recurrent parent being the pollen producer.

The cross M. 112/34 x M. 63/39, designed to combine high sugar and high yield capacity in one or two clones, has been repeated frequently, but has failed to produce the desired combinations, the progeny exhibiting great vigour, but lacking in sucrose. Selections from that cross, for instance, M. 24/47, a variety cropping well under diversified conditions, have been crossed back to M. 112/34, the pistilate parent, with the object of producing high juice quality clones.

Probably most interesting is the cross B. H. 10/12 x M. 63/39, which has yielded a number of selections of the requisite standard for inclusion in second trials. Two of these flowered in 1954, but could not be crossed with B. H. 10/12 which failed to tassel during that year ; B. 34104, a direct derivative of B. H. 10/12 had to be used instead. S. C. 12/4, a sister of B. H. 10/12, if available, would probably have served a better purpose.

B. H. 10/12, one of the richest canes ever planted in Mauritius, arrows sporadically, and is not a prolific parent when used either as a male or a female. Out of the few varieties bred from it locally, none has so far proved a promising parent. Experiments are in progress to try to induce arrowing in this variety.

Other crosses, such as B. 34104 x M. 213/40, yield progeny none of which appears capable of approaching the standard varieties in sucrose content. Attention has also been paid to the following crosses B. 34104 x M. 63/39, Ebene 1/37 x M. 63/39 and M. 11/43 x M. 63/39. M. 11/43 has exceptionally good juice, but appears susceptible to ratoon stunting disease.

As can be seen, therefore, back crosssing is still at its beginnings in this country, and it is as yet impossible to forecast its value as a breeding method for evolving high quality seedling varieties. Recurrent selection can only be a side-line to the general breeding methods which have already yielded fruitful results not only here but in most countries. The varieties M. 134/32, which has still pride of place in this colony, and M. 112/34, which does admirably in certain localities of the island, are both high sucrose yielders, but there remains the possibility that richer and earlier maturing types may be evolved by back crossing or using basically rich parent varieties. The case of Ebene 1/37 deserves special mention as it is one of the richest home-bred varieties. This cane has for parents P.O.J. 2878, Ube Marot, R.P. 8 and M. 27/16. Its high sucrose content has, in all probability, been handed over from P.O.J. 2878, the other parents being of low or very low quality. The case of Ebene 1/37 is interesting as it exemplifies the occurrence of a rare superior segregant from populations bred from parental types poor in sucrose but good otherwise.

Steps have been taken to increase the range of high-sucrose parents and to concentrate more on crosses likely to yield offspring of promise. Among late introductions are N. Co. 310, 27 M.Q. 1124 and 28 M.Q. 1370, which are still undergoing quarantine, and will not be used before some years.

In Australia, there has been a different approach to the production of varieties associating vigour and quality. The spectacular results obtained with pure-line breeding of parental material followed by intercrossing these pure lines in plants such as wheat and maize, has led to the consideration by Gard (2) of planned selfing as a breeding method. It is hoped that by selfing successively some of the high sucrose parents, parental varieties homozygous for certain economic characters may be obtained. Stevenson (3, 4) in Barbados adopts the same method of building up elite breeding stock. Naturally, paucity of data precludes any categorical pronouncement as to the practicability of this method of sugar cane improvement.

Simpson and Duncan (5), investigating the effects of selecting within selfed lines on the yield and other characters of cotton, found that, in spite of selection pressure to improve desirable qualities in four best varieties, there was no marked gain in any character except in lint length, and an average loss of 15% in yield of seed cotton.

Plant Breeders must therefore be at odds in their opinion on the value of continuous selfing as against no selfing at all in cane breeding. Perhaps the answer to the problem is to steer a middle course.

In Mauritius selfing has been practised with the main object of obtaining information on the degree of self-fertility of pollen-producing parents, and to ensure whether they can be used as females in reciprocal crosses. Selfing produces very generally few or very few seedlings in Mauritius, so that the probability of selecting desired parent types is very low unless the operation be repeated on a certain scale, which would be at the expense of the number of biparental crosses. Even in the case of the heavy pollen producers tested, selfs do not loom large ; a fact of considerable practical importance, since such varieties may safely be used as females. For instance, both S.C. 12/4 and M. 63/39 yield a large amount of pollen in the lowlands particularly, but the seedlings derived from a cross between these two varieties were obvious hybrids. It would appear that, in the cross S.C. 12/4 x M. 63/39, the pollen of M. 63/39 is prepotent. This phenomenon might be of considerable use in back crossing when it is desired to combine the traits of two specific parents both of the male sex.

EARLY MATURING VARIETIES

The position as regards early maturers is as follows. There are now under cultivation the varieties M. 112/34 and Ebene 1/37 which have better juice than

M. 134/32 early in the season, but are restricted to definite areas, the former to the warm coastal regions and the latter to the wetter localities of the island.

It is possible that one or two of the Barbados varieties such as B. 34104 and B. 37172 may be early maturers. Samples taken in pre-release trials in July showed that both these varieties have a Brix value nearly one unit higher than that of M. 134/32. This higher Brix figure may, however, be offset by a higher fibre content.

The only interesting cross which produces early maturers is Co. 281 x M. 63/39, but unfortunately the progeny from this cross has thin stalks and arrows heavily. M. 63/39 is a very thick cane, but when mated to Co. 281, the small diameter of the stalks of Co. 281 is " dominant ". A ray of hope, however, emanates from the variety M. 147/44 which appears to be an exception as it is of good thickness and flowers sparingly.

New high sucrose parents have been used for the past few years and may help solving the problem at stake. These are B. 34104, B. 37172 and M. 336, Pindar, N. Co. 310, 27 M.Q. 1124 and 28 M.Q. 1370 will not be available before some time.

The following steps have been taken for the selection of early maturers :—

(a) seedling selection to take place early in August. The refractometric Brix during this month appears to cover a wider range than in October and November due probably to the high percentage of late maturing canes ;

(b) reaping trials including varieties with commercial or near-commercial status in July, September and November. The trials are replicated in time and space, so that it may be possible to determine in a reasonably short time, that is, before they are released, whether the varieties under trial are early, medium or late maturing. With the present method of analysing 10 stalks per plot of a trial, sampling errors are frequently high and tend to mask maturity gradients so that a certain number of samples is necessary to obtain reliable analytical figures.

VARIETIES FOR SUB-NORMAL ENVIRONMENT

Interest in the breeding work is also focussed on the production of varieties adapted to the leached soils of the cool wet upland regions totalling some 20,000 acres. Experiments to rejuvenate these soils by the incorporation of basalt dust have been in progress for many years, and have shown that yield increases of the order of five to six tons of cane per acre per annum are to be expected under such super-humid conditions following single applications of nearly 200 tons per acre of crushed basalt prior to planting. It should be borne in mind that experiments on crushed basalt are necessarily of a long term nature and should be repeated over the years, particularly in ratoons, to assess the cumulative effect of the basalt on cane yields with which is bound up the whole economic aspect of the problem. There is no doubt, however, that a better way of rendering these soils more productive, is intimately bound up with the breeding of suitable varieties. The variety Ebene 1/37 is eminently suited to these soils, but its susceptibility to chlorotic streak is a potential danger. Another variety which crops well on these soils is B. 3337 which, unfortunately, has not always good juice.

There are now two sub-stations in the high-rainfall zone, where the production of suitable varieties is being accelerated. In the light of experience recently acquired, it would appear that, for successfully raising seedlings in such sub-normal environment, the following conditions should be fulfilled :—

1. In view of the incidence of the pink borer, seed maize, to act as a borer trap, should be sown in the interlines of the seedling plot ten to fifteen days before actually transplanting seedlings.
2. If the number of potted seedlings is in excess of requirements, the weaklings should be discarded as they are likely to die off soon after transplanting. Natural selection is more effective in weeding out the weaker seedlings in the cooler high rainfall localities.
3. The seedlings planted in December should be allowed to grow slowly as they have to occupy the ground for nearly twenty months, unless they can be harvested the following year and selected in ratoons.
4. It would appear that seedlings planted on land having borne other crops than sugar cane for a certain period do better than those planted in fields which have remained under cane for a continuous period of years. A scheme whereby sugarcane could be rotated with other crops would conseqently be advantageous. A crop of green dressing preceding seedlings might help lessening chances of infection by pathogens through the medium of old root stocks.

   Seedlings selected in super-humid areas undergo preliminary testing in these areas before inclusion in pre-release trials on estates displaying the same climatic conditions.

Lack of sufficient data precludes the formulation of a definite crossing programme for these areas. It may well be that Ebene 1/37, in combination with several perennial types, will yield valuable seedling varieties for cultivation under these unfavourable soil and climatic conditions. B. 3337 would be possibly a potential producer of good canes if it were not a shy arrower.

PLANTING MEDIA FOR FUZZ AND SEEDLINGS

Seed and potting composts prepared according to modified John Innes formulae (6) were compared to the ordinary soil-manure mixture as planting modia for sowing the seed-bearing fuzz and for potting seedlings. Turfy loam and peat have been replaced by top soil and decaying wood respectively. No chalk was added to the composts as coral sand rich in CaO was used in the experiments. No hoof and horn was added to the potting compost. The top soil for both the seed and potting composts and the soil-manure mixture have been steam-sterilized at low pressure at 93° C for five minutes and 98° C for four hours respectively.

There was no difference in the times taken for fuzz germination, in the number of seedlings obtained, and in the rate of growth of seedlings between the experimental and control flats. What should be emphasized is that there were a few cases of damping-off disease in the flats containing the soil-manure mixture, and none in those containing the modified J.I. compost. This is most encouraging as the disease frequently takes a heavy toll of seedlings which die by the thousands in heavily infected flats.

The experiments also revealed that the best stage for pricking seedlings is about five days after germination of the fuzz, that is, as soon as they can be handled. They then do not suffer a setback. Seedlings transplanted to pots showed signs of nitrogen deficiency due to the absence of hoof and horn. A little sulphate of ammonia added to the plots rapidly corrected the deficiency.

IMPACT OF RATOON STUNTING DISEASE ON THE BREEDING WORK

The discovery made in 1954 that ratoon stunting disease exists in Mauritius has prompted the Plant Breeding Division of the Sugar Industry Research Institute to take certain steps regarding (a) preventive measures to avoid infection of seedlings and varieties in second trials ; (b) the formulation of a crossing programme with the object of evolving resistant varieties ; (c) the rapid assessment of ratooning capacity of varieties likely to be released for commercial growing.

The preventive measures will comprise the use of sterilized knives to cut selected seedlings and canes from second trials and pre-release trials. The sampling of seedlings and varieties in second trials for reading the refractometric Brix will assist in the dissemination of the virus unless the juice sampler be disinfected. Sterilizing juice samplers between consecutive samples is, in the opinion of the writer, a difficult and time-consuming operation. Sometimes several hundred varieties have to be examined for Brix each year, and it is therefore proposed that canes in second trials be cut first and then punctured for Brix determination.

Evidently the formulation of a breeding programme to produce varieties resistant to ratoon stunting disease must be as yet a hit-and-miss affair. The varieties under cultivation, namely M. 134/32 and M. 112/34, can be considered commercially resistant and will be continued to be used until better parental types are available. While the first variety has declined in certain parts of the island, particularly on the high plateau, perhaps due to the combined effects of stunting disease and chlorotic streak, it has still retained stamina in many other areas and continues to give a good account of itself. Although M. 112/34 has not mothered a cane of commercial status up to now, it might yield promising seedlings when combined with new parental varieties.

Selection of components for crosses made in 1955 comprised :—

resistant x susceptible varieties, and
susceptible x susceptible varieties.

The second category of crosses included the very susceptible varieties D. 109 and Co. 419.

Following the results of preliminary trials for rapidly assessing the ratooning capacity of cane varieties by growing five to six month ratoons, and comparing total yield of cane and leaves with that of standard varieties (strong and medium ratooners), new trials, on the latin square layout, have been laid down under a diversity of environmental conditions. Cuttings were hot-air treated at 54°C for 8 hours in a laboratory oven in order that the possible presence of the virus may not create a bias in the data and confuse the issue in ratoon. One trial was planted with untreated cuttings, and its results will be compared with those of the other trials.

It is hoped that these ratoon capacity trials, apart from rapidly providing data on the ratooning qualities of new varieties, will also give useful information on their reactions to ratoon stunting disease at an early stage of the breeding work.

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In the absence of the author the following paper was taken as read.

Paper

THE ADVANCE OF SUGARCANE BREEDING IN TAIWAN THE DEVELOPMENT OF P. T. SEEDLINGS

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Sugarcane improvement work was inaugurated in Pingtung, Taiwan, in 1946 with a view to breed new varieties of sugarcane for commercial planting in Taiwan. Table I would show the progress reached todate.

TABLE I

Years	No. of crosses made	No. of tassels made	No. of seedlings produced	No. of seedlings per tassel
1946	441	613	72,586	118.4
1947	389	929	147,623	148.9
1948	573	1059	197,800	186.7
1949	431	814	187,025	229.7
1950	344	654	113,293	173.2
1951	535	879	191,689	218.0
1952	490	764	113,188	148.1*
1953	363	806	353,965	439.1
1954	568	866	139,498	161.0**

The low percentage of viable seeds results from :

1. It would be evident that the Station has raised annually one to two hundred thousands of seedlings.

2. The number of tassels per cross is less than two, showing that the combinations are rather diversified instead of concentrated.

3. The number of viable seeds is rather small and the number of seedlings produced per tassel is around two hundred.

In the first place, with exception of Hawaii, the scale of hybridisation is rather larger compared to the breeding programme of the other sugarcane breeding stations both of the east and west-hemispheres. Secondly, as a rule, the diversified crossings are usually due to the great number of crosses classified as trial rather than commercial. The cause of this in general is either due to the lack of suitable elites for breeding, or, too many problems to be tackled by the cane breeder. In our case we encounter both. As to the third, we have improved our crossing technique as well as the seedling raising work. In some of the commercial crosses, in fact, we obtained one to five thousands of seedlings per tassel. The low production of seedlings usually occurred in Puli and Hengchuen Substations where the crossing works were done under extremely unfavourable conditions (See Map).

In the previous year, the early Spring rains plus the short sunshine durations in Autumn are notably favourable to the flowering of sugarcane plant. This is especially true so far as the sunshine duration is concerned. The average daily sunshine duration is comparatively short throughout the year favouring the flowering of the short sunshine-durations varieties of sugarcane (2). Certain varieties which did not flower since 1946 in certain regions flowered prolificly last year, as for instance Badila in Puli and C.P.34-79 in Pingtung. The profuseness of flowering of some of the scarcely flowering parents has enabled us to obtain better combination in our crossing work and the crosses made have proved effective.

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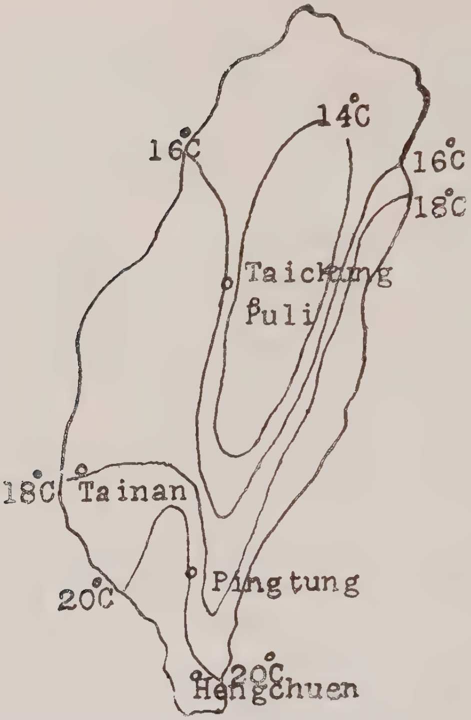
*The occurrence of typhoon during arrowing period (November 14, 1952).

**The unusual night showers during the crossing season.



Map : Showing the locations of Pingtung Sugarcane Breeding Station and Sub-stations of Puli and Hengchuen with minimum winter temperature.

Table II would show the number of crosses made during 1953 and 1954 season.

TABLE II

Crosses	No. of tassels made	No. of seedlings produced
Commercial Crosses	568	1,39,498
A(CCA)	367	75,627
B(CCB)	201	42,346
Trial Crosses	9	544
Basic Crosses	52	20,981

Of the commercial crosses, the commercial cross A, or CCA, have made 367 tassels of which 177 tassels are crosses of three female parents with 10 to 15 male parents. The seedlings produced from the crossses of these three female parents were estimated to be 80,000, approximately 58% of the commercial crosses In a single cross, 5 to 30 tassels were made in duplication and the number of off-springs was 10,000, or more.

In the commercial cross B, or CCB, we used some of the 48-, 49- and 50-elites for the first year in our commercial crosses. Owing to the inadequacy of enough tassels, most of the elites were used as female parents instead of male parents, although the stalk-rind hardness of our female parents has usually rated from grade 1 to 3. Experiences from the recent years have shown that the off-springs of the " soft " female parent, stalk-rind hardness rates below 3, are apt to be "soft " seedlings, though exceptions have always occurred.

With a view to accomplish the bulk-scale crosses of some of our elites in commercial crosses, we used the " layering technique " as well as "sulphurous acid technique " to bring all the crosses under control conditions. The success of " fooling method " found by Louisiana botanists by daily shortening the day length with a minute in the photoperiodic controlling room to " fool " the treated sugarcane plants to flower made in last year has initiated a plan of 100 crosses made in the photoperiodic controlling room for the coming season. The cross under control conditions is important not only to save the tassels of the desirable elites in crossing but also to increase the number of viable seeds per tassel. Since our hybridisation work was done under extreme unfavourable conditions of north-east monsoon and low temperature at night, the crossing under control conditions would definitely increase the number of viable seeds and consequently the number of seedlings germinated. In fact, we doubled the number of seedlings of some of the commercial crosses under windless conditions. Furthermore, we have successfully increased the number of seedlings by improving the "cage technique" to increase night temperature.

In order to obtain a clear picture of the breeding progress of this Station, a brief statement on the terminology of certain terms used in this Station is probable in need. In commercial cross we mean the cross we make for the purpose to produce commercial varieties which are suitable for Taiwan in using as commercial planting. Those parents had been found to " breed true " for certain traits which possess a high degree of dominance to retain desirable characters repeatedly in combination and usually produce superior new seedlings are selected as our "elites". The crosses made from these elites are called commercial crosses. Those commercial crosses had been repeatedly produced higher percentage of superior seedlings were classified as "commercial cross A", which are repeatedly on a large scale crosses, while those newly proved crosses classified as " commercial cross B ". Should one of the parent of the cross has been proved superior phenotypically from the general appearance of the population while the other promising in special character or characters yet the phenotypes of the combination are not predictable, called " trial cross." To the basic cross, we refer to those crosses which involve the nobilization of the wild species, or relatives of *Saccharum officinarum*. The Basic crosses aim only to produce desirable parents, purposing to introduce certain qualitative characters into our elites, such as disease resistance, stem-rind hardness and adaptability to adverse conditions.

During the past ten years, efforts had been made to synthesize desirable varieties for commercial planting in Taiwan and the following characters had been taken as criteria in selection :

1. *High sucrose content.* First-year seedlings were determined exclusively with hand refractometer while second-year seedlings were determined both in field and in laboratory at harvesting season, mostly from January to March of the year. Anyone lower than the standard commercial variety is to be discarded.

2. The tonnage per hectare must be higher than the standard variety in normal year.

3. *Stem-rind hardness.* The rind hardness of the millable stalks must be above grade 3 according to our rating system of stem-rind hardness. Soft canes are disqualified for commercial planting no matter howgood is the other characters.

4. The ability to sustain regular growth during the heavily rainy season as well as in dry, low temperature winter season.

5. *None, or, few-tasseling.* The year-old seedlings must be free from tasseling. As our experience thus far, should the year-old seedlings tassel in the first year, there is no exception that they would tassel in the following years had they were planted for eighteen months.

6. *Disease resistance.* Only those seedlings which are resistant to mosaic, leaf scorch and red rot were selected for a sexual propagation. Recently the sporadic occurrence of the downy mildew disease in this island has added one more disease in our list of disease resistance test.

7. *Solidness.* The solidness of the stalk is the first requirement of the overall qualifications in our selected seedlings.

As we have stated before, for years we have put all efforts in searching, or properly, to develop, our desirable elites for the commercial breeding purposes. The results of the basic crossing have enabled us to utilize the desirable characters of Narenga Bor. and those of Miscanthus Japonica. In our 51-series, among the seedlings selected, we obtained 243 out of 1,853 (13.10%) of the first year seedlings and 49 (20.0%) of the scond year seedlings in the same cross of F_2 of Narenga. It broke the record not only on the basic crosses but also on the commercial crosses prior to 1950. The fruitful outcome shows that the basic cross is not a kind of fancy work, instead, it deserves to intensify the breeding programe of it.

According to the result of the field studies of the offsprings of *S. officinarum* with N. Bor., M. Japonica, Imperata cylindrica and *S. Spontaneum* of Taiwan, we are especially interested in their freedom from diseases and the growth potentiality shown by them during the dry and low temperature winter season. As most of the other varieties of sugarcane appeared in this period senescently with very few elongative growth on the top of the stalks, however, the offsprings of these distant crosses are still growing and juvenile.

Furthermore, the tendency changing from diversified to concentrated crosses has narrowed the crossing between several elites which are mostly homozygous for limited genes or genomes. Should the bulk-scale crosses continue for several years, the shifting from diversified combination of genes or genomes to concentrated combination would consequently minimize the number of genes or genomes in synthesis. This is especially true in the continuous utilization of the superior new seedlings in further crossing for commercial crosses. It results to shift the gene frequencies in one direction. In order to widen the combination of the genes or genomes of the superior parents and to develop continuously new elites for commercial crosses, it is obvious that due effort in basic crosses would provide a bright future for the sugarcane improvement, if the sugarcane breeders carefully explore the traits of the wild parent plants. It is for this purpose that this Station has always made 10 percent of crosses annually for the basic crosses, continuing to develop new elites for the use of commercial crosses.

In making commercial crosses we have considered seriously on : (1) sugar content, (2) vegetative vigour and (3) freedom of tasseling. For practical purposes, we divide our elites into two groups : the sugar-carriers and vigour-carriers. Of the former, we usually use as male parent while the latter is used as female parent plants. Those parent plants have repeatedly proved to be sucrose-carriers are shown as following: P.O.J.3016, F.110, F.108, F.134, P.T. 46-220, P.T.48-1, P.T.46-156, P.T. 49-143, P.T. 47-1079N,P. T. 48-21, Co.290, C.P.36-13, C.P.34-79, and P. T. 51-2.

While those proved to be vigour-carriers are :
P. T. 41-161, P. T. 41-1114, P. T. 46-73, P. T. 46-150, P. T. 46-144, P. T. 43-52, P. T. 50-533, H.32-8560, F.133, Co.421 , and P. T. 48-80.

Began in 1913, the sugarcane breeding work of this island can be clearly divided into two periods, if the main parent plants used in making crosses for commercial purposes were based :

1. P.O.J. 2725.

The first series of native seedlings bred in this island is F-seedlings which were mostly of the progenies of P.O.J.105, P.O.J.143 and P.O.J.181. These parent plants again were the progenies of Black Cheribon and Chunnee. Most of the seedlings raised within this period were inferior and not until 1922, a tough, hard, medium, red cane, F.46, was produced. It happened that P.O.J.2725 was introduced from Java in 1920 and the cross of P.O.J.2725 with F.46 in 1927 produced F.108. This was the first cane became commercial variety later produced natively in this island. P.O.J. 2725 was widely used then as the female parent plant in the years from 1922 to 1928, although P.O.J.2364 was used in the same period with less extent. During this period, P.O.J.2725 became the main, if not only, variety of sugarcane having 90% of the crop acreage annually. The boom of the sugar industry of this island encouraged much to the sugarcane breeding work.

2. *P.O.J.*2878 *period.*

P.O.J.2878 was first introduced into this island in 1924 and repeatediy imported in the following years until 1928. It owed probably to its popularity to be used intensively as one of the important parent in breeding in this island since 1926. It was until ten years later, 1936, a seedling of Co.290x P.O.J.2878, F.134 was produced This is medium, solid, soft but rather short cane with high sucrose content. It retained most of the characters of Co.290 but enlightened with certain visible characters of P.O.J.2878. This period probably began in 1928 and ended in 1948, a period of which P.O.J. 2725 was still to be the important variety for commercial planting and not until 1940, the acreage of F. 108 was begun to take the place of it. P.O.J.2725 succumbed as a result of heavy infestation of sugarcane borers and physiologically senescent disease with necrotic tissues within the bottom internodes of the stalk.

The rise of F.108 seems not much help to the war-torn sugar industry of this island, the scarcely tillering plus the susceptibility to mosaic has made this variety run out rapidly. The largest acreage occupied by this variety was 52.48% of the total acreage of the crop year of 1947-1948.

In facing the need of the new varieties to replace the " degenerated " commercial varieties, P.O.J.2725 and F.108, we have to push a well planned breeding programme to tackle fundamentally the varietal problems of this island. First, we intensified the regional varietal test to search for better varieties for commercial purpose to replace the old ones. The adding of F. 134 in 1950 and N.Co.310 in 1952 in the list of commercial canes shows that the varietal improvement has been successfully done to a certain extent. However, we would not satisfy the present outcome until we can produce the varieties which can fulfil our requirements and adapt the climatic conditions of Taiwan.

The annual losses from dead cane have figured from lowest in 5% to highest in 20 to 30% and the menace of typhoon exists every year though it may, or may not, occur. It is apparently not safe for the sugar industry if our commercial varieties of sugarcane are vulnerable to fracture or to rat damage. Should our sugarcane breeding programme mean anything then the main elites of our commercial crosses for the near future would be of the type of varieties of "hard" canes. We have developed a technique to standardize the measurement of the stem-rind hardness by which the stem-rind hardness of any variety can be rated. The determination of the stem-rind hardness was made for the second year seedlings which have been very promising in most of the agronomic characters. Any variety rates below grade 3 would not be desirable and are mostly to be discarded. (3). The examples of the grades of stem-rind hardness of the known varieties of sugarcane are given in the following as illustration :

Varieties	*Grades*	*Varieties*	*Grades*
P. T. 43-52	1	H.32-8560	2
P. T. 50-62	1	P.O.J.3016	5
P. T. 51-11	1	F.134	4
C.P.34-79	2	N.Co.310	3
Co.281	2	F.108	3
Co.331	1	P. T. 48-80	3

The stem-rind hardness is one of the heritable characters of sugarcane and was found to be transmitted to offsprings by the proper parent plants. The discovery of this character has made the synthesis of new varieties of sugarcane which can really stand the drastic changes of climate of Taiwan. Some of our seedlings of the 50-and 51 series such as P.T. 50-2, P.T. 50-62, P.T. 51-11 and P.T· 51-2 are the representatives of our new varieties with stem-rind hardness rating grade 1. All of these varieties had been performed excellently in the regional tests of sugarcane varieties in the recent years.

The greater stem-rind hardness with 13-14 percent of fiber (fiber % cane) has become one of the traits important for commercial varieties in Taiwan.

The sucrose content is important and has been searched for a long time by the sugarcane breeders of this island. Owing to the rather higher temperature, usually 15° to 17°C during the harvesting season, the maturing process of the sugarcane plant is notably slow and the sucrose content percent cane is usually 10 to 11 percent at the end of December of the year. It is desirable to have early and high sucrose content varieties of sugarcane so as to enable the crushing season strarted as early as November. Since 1946, attempt has been made to use some of the high sucrose varieties, such as P.O.J.3016, F.134, C.P.36-13, C.P.34-79, and P. T. 47-1079N, as the parent plants for breeding purpose, however, difficulties encountered are that these varieties either flower too early or not flower at all. Not until 1948, we were successful to make crosses of these varieties with some of our elites and more than ten thousand of seedlings have been produced since then. Among these seedlings, the P. T. 48-1, P. T. 48-38, P. T. 48-59, P. T. 48-70, P.T. 48-80, P.T. 49-713, P.T. 50-62, P.T. 50-777 and P.T. 50-2 have also been used as parent plants in recent years. Exception with C.P.36-13, which was highly susceptible to leaf scorch disease of sugarcane, had not been used in our crossing now. The remainders were used in our commercial crosses and some of the very promising varieties had been obtained. The offsprings of the above mentioned varieties are mostly non-flowered, or scarcely flowered in this island. In addition, they are mostly very resistant to mosaic disease of sugarcane.

The average yield of cane per hectare of this island is from 70 to 80 metric tons, it is lower than in Java and much lower than in Hawaii. It was found that the diversity of soil types and lack of irrigation have complicated both the problems of cultivation and varieties. For instance in unirrigated, heavy clay soil regions, the fan-shaped tillering variety, like F.108 usually produces fewer tillers than other varieties thus the number of millable canes per hectare of this variety is usually 45,000 to 50,000. The same is P.O.J.2725, a dish-shaped tillering variety, in unirrigated, fine, sandy soil along the seashore of this island. Aiming at more millable canes per hectare, say 80,000, the releases of bowl-shaped and cup-shaped tillering varieties for commercial planting would give better chance for successful cultivation so far as the soil conditions and the educational level of the cane farmers are considered. The type of tillering was found again heritably transmitted from the parent. The crossing of the fan-shaped tillering variety with that of bowl-shaped tillering variety has obtained in majority of bowl-shaped tillering offsprings. It is anticipated that the better choice combination in crossing and the careful selection would finally eliminate most of the offsprings of the undesirable type of tillering in the second-year selection. This would help very much on the successful cultivation of the newly released varieties for commercial planting.

Growth potentiality has long been a varietal problem of sugarcane in Taiwan. Some varieties grew fastly and vigorously both at the beginning of the grand period of vegetative growth during the rainy season, however, they were fatally struck either by continuously heavy rains, or, by typhoon, or both, and the following of long dry season has been detrimental to both in sucrose content and the maturing process of the sugarcane plant. The apparent detriments are the slowing down of the vegetative growth and the increase of the number of dead canes in the field. Obviously, the continuously heavy rains during the rainy season creating an anaerobically poor drainage condition which has caused most of the roots to death and the shedding of the green leaves by the typhoon in autumn and the north-east monsoon in winter have caused most of the varieties of sugarcane to succumb before normally maturing process has been commenced. The shedding of the green leaves has immediately caused the cessation of the vegetative growth of the whole stool. A good illustration is the outcome of the detriment of the typhoon with 15.8 metres per second occurred in July 4 of 1953 in Pingtung. The growth rate of varieties with grade 1 in stem-rind hardness such as P. T. 43-52, P.T.50-62 and P.T. 49-729 decreased markedly only in the following month, August. However, the effect on those varieties with grades 3 and 4, such as N. Co.310, P. T. 48-80, P. T. 48-67, and P. T. 48-1, lasted from July to September, the following three months immediately after typhoon. The rapid recovery of the former was attributable to their better stand in the field, while the latter have been lodged badly on the ground.

The degree of vegetative senescence at the end of the rainy season and the commencement of dry, low temperature in Winter is a reliable indicator of growth potentiality of the varieties of sugarcane and has been used effectively by us to eliminate most of the undesirable seedlings.

The cross of two usually tasseling, or early tasseling, parent plants usually produces tasseling offsprings (2). Tasseling obviously is a heritable trait of sugarcane. However, the cross of one tasseling parent plant with one not usually tasseling, or even not tasseling in the sugarcane district at all, usually produces high percent of non-tasseling offsprings. It was found that the usual-tasseling varieties in Taiwan are mostly of long sunshine-duration varieties, averaged 5 to 6 hours daily, tasseling usually in November while those of non-usual-tasseling are of the short sunshine-duration varieties tassel only under sunshine-duration, averaged 3 hours daily, in the mid December of the year. The cross of one short sunshine-duration variety with one long sunshine-duration variety has intercepted the flowering photoperiod of the both parent plants, thus reduces the percent of tasseling of the offsprings. The application of the principle of interception of photoperiod has enabled us to produce very promising varieties which tassel very late in season, or not at all, in most of the sugarcane districts of this island. Examples are P.T. 46-144, P.T. 48-80, P. T. 48-1, P. T. 50-2, P. T. 50-62 and P. T. 51-11.

As to the breeding of disease resistance, we have fought deliberately four major diseases of sugarcane during the recent decade. They were the mosaic, red rot, leaf scorch (Stagonospora Sacchari) and downy mildew. The cross of the resistant varieties to mosaic with some of our elites, such as P. T. 46-220, P.T. 48-80, P. T. 48-21 and P. T. 43-52, produced the offsprings in majority free from mosaic. This has been helped much by the elimination of the susceptible variety F.108 in commercial planting. In the mean time, the red rot susceptible varieties F.110 and F.109 have been out of planting in sugarcane district of the west coast. It would be sure that the inoculation test of mosaic and red rot diseases on the second-year seedlings had been used effectively in eliminating the susceptible ones. And the extinction of these two diseases of sugarcane is anticipating in the not very distant future. In fact, mosaic and red rot diseases had not caused any loss in the recent years in our sugar industry. The sudden appearance of leaf scorch disease of sugarcane in 1950 causing much alarm on our breeding work and resistant test by " spindle inoculation " had been carried annually with the second-year seedlings. Besides, some drastic measures had been taken to minimize the spread of the pathogen. The newly bred varieties such as P. T. 50-2, P. T. 50-62, P. T. 51-2 and P. T. 51-11 showed various degrees of resistance to leaf scorch disease of sugarcane. It seems that the release of these new varieties of sugarcane would finally bring this disease under control.

Although downy mildew disease of sugarcane appears sporadically in many parts of this island, yet there was not much loss in commercial planting thus far. However, there is no reason that this disease would not become menace to the sugar industry in the future, should this disease not suppress completely. This disease has occurred in this island for more than four decades becoming epidemic in the recent years owing to the increase of commercial planting acreages of F. 134, which is susceptible to this disease. Since 1950 we were aware of the importance of the disease. Resistant elites for hybridisation purpose were selected and crosses had been made since that year. In fact, more than ten thousands of these crosses had been produced.

Evidences accumulated show clearly that most of the offsprings of F.108, Badila and Badila' seedlings were highly resistant to downy mildew disease of sugarcane. Selections of F_1, F_2, and F_3 of Badila perform promisingly both in agronomic characters and in disease resistance to downy mildew. Three years ago, H.32-8560, Co. 290 and Co.281 were added to the list of breeding elites for the breeding of resistance to downy mildew disease of sugarcane. The offsprings of these parent plants also showed hopefully in this respect.

In conclusion, the outcome of our sugarcane breeding programme during the recent ten years has enabled us to produce some hard-cane varieties which stand very well during the typhoon season. It is believed that the release of these new varieties of sugarcane would consequently minimize the losses from the destructive typhoon. The excellent performance of P. T. 50-2, P. T. 50-62 and P. T. 51-11 in the regional varietal tests in the recent years showed that it is the first time of the sugarcane breeding history of this island to have such beautiful varieties of sugarcane having the qualities to meet the need of the climatic conditions of Taiwan. It is one of the triumphs we have had in our recent sugarcane breeding work in fighting with the damage of typhoon.

Besides, the alarms of mosaic disease on F.108 and F.110 in 1948, leaf scorch disease on F.134 in 1952 and downy mildew disease on P. T. 43-52 in the current year press tightly on our sugarcane breeding work to concentrate all our efforts on disease resistant breeding.

The relationship between the pathogen and host of the downy mildew disease of sugarcane is still not well understood. It was found that those varieties good for lateral-sprouting propagation are usually more susceptible than the poor ones. Those fields used lateral-sprouts, instead of seedpieces, as planting materials are apt to find more diseased stools than the latter, if the variety is susceptible to the disease. It is presumably that the conidia of the pathogen have a better chance to fall down, instead of straying, through the air to get infection on the tissues of the host. The lateral buds of the stalk seem to be the best prey for the pathogen as they are the actively respiratory organs of which the suitable nutrients and water are available. Miyake (7) first reported that the conidia fell on buds penetrating through the prophylum after twenty four hours and symptom appeared within two weeks as the seedling is 4 to 5 inches high. Kayashima (1) confirmed Miyake's finding and presented with further evidences to show that bud infection is one of the important methods by which the pathogen of downy mildew disease of sugarcane spreads the disease.

Finally, the situation of the drastic change of the commercial varieties in this island is especially serious. This is illustrated in the following Table :

PERCENTAGE OF AREA UNDER THE IMPORTANT COMMERCIAL VARIETIES OF SUGARCANE IN TAIWAN IN YEARS FROM 1951 TO 1954

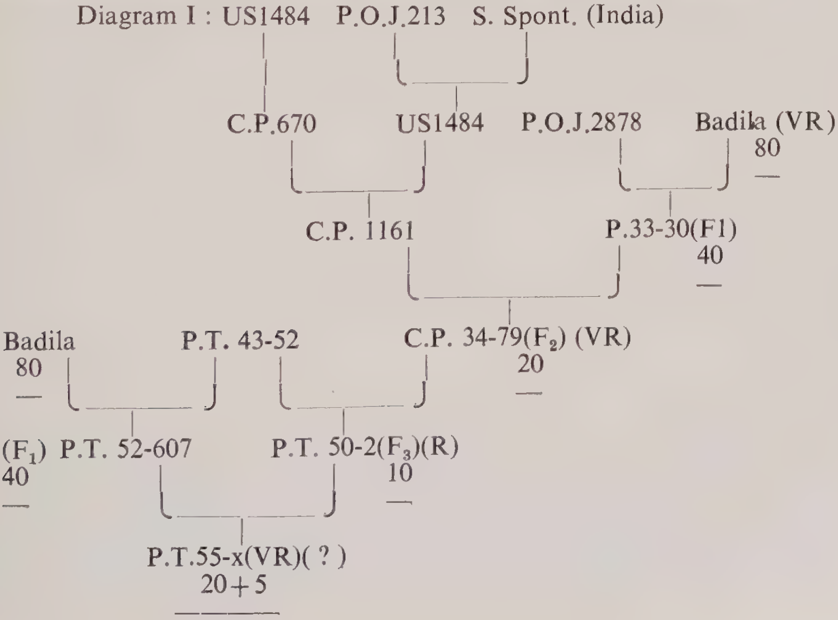
Varieties	1951-1952	1952-1953	1953-1954
P.O.J.2725	7.69	3.24	0.31
P.O.J.2883	31.52	29.32	18.27
F.108	40.75	43.14	9.71
F.134	0.04	16.99	23.26
N :Co.310	0.01	0.56	42.99

The fall of F.108 seems definitely following the fate of P.O.J.2725 and in fact, the acreage of F.108 is still going to drop down in the crop year of 1954-1955. As to F.134, the losses from the typhoon of July 4 and November 18 in 1953 figured from 10-20% to as high as 60-80%. It has lost most of its acreage in Taichung and Tainan (centre and southern parts of the island) in the crop year of 1954-1955. The heavy losses of F.134 from the typhoon of the said year have proved that the soft cane is absolutely not fit as commercial varieties in Taiwan. P.O.J.2883 again has a trend to decrease in acreage during the recent years and it is believed that the acreage of this variety would be reduced in the following years due to its low sucrose content and high percent of dead cane in harvest. Should our commercial varieties remain the same as in the above Table, then, within two to three years to come N :Co. 310 would be the only commercial variety of this island. It is apparently that we need more varieties of sugarcane for commercial planting to minimize the losses from insect pests, diseases and typhoon on the one hand and to provide better millable canes and better juice for the mills on the other.

The sporadic occurrence of the downy mildew disease of sugarcane in districts of the west coast of the island makes the varietal problem extremely serious in the recent years. The high yielder, P. T. 43-52, performed excellently throughout the island, outyielded the standard commercial varieties becoming the most superior variety ever bred in this island. It has been released in the last two crop years for commercial planting but suspended in the current crop year for commercial planting owing to its susceptibility to downy mildew. F.134 and P.O.J.2883 were susceptible also but in less degree. The results of the regional varietal tests showed that most of the varieties joined in the tests were susceptible to downy mildew, even the popular varieties such as H.44-3098 and Co.419 were very susceptible. H.32-8560 and H.37-1933 seem resistant to downy mildew yet the commercial value of these varieties was not fully confirmed. The very susceptible of these varieties to leaf scorch disease of sugarcane again throws a shadow on their commercial value.

As to the resistant breeding to the downy mildew disease is concerned, some of the reults are especially interesting as shown in the following diagrams.

Diagram I :

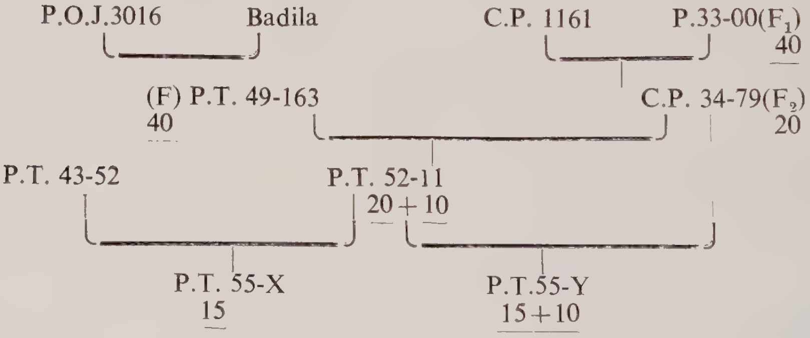


In bracket, VR denotes "very resistant," while R indicates "resistant" to downy mildew disease of sugarcane having been proved in Taiwan. The numerals with underline designate the theoretical number of chromosomes contributed by Badila as a parent in crossing.

Two important points should be stated at this moment, firstly, in crossing with a very susceptible variety such as P.O.J.2878, or P. T. 43-52, no matter you use Badila as female parent or as male parent, the seedlings produced from these crosses are mostly resistant to downy mildew disease. The gene, or genome, of resistance is usually dominant while susceptible one to be recessive, at least it is true in the case of Badila. Secondly, a F_2 of Badila, such as C. P. 34-79, crossed with the other susceptible parent P. T. 43-52 produced P. T. 50-2, which is quite resistant to downy mildew disease. Theoretically, P. T. 50-2 possesses only ten chromosomes from Badila. It is reasonable to assume then ten chromosomes of Badila is minimum for the resistance to the disease of downy mildew. Since C. P. 1161, one parent of C. P. 34-79, has very high percent of blood of P.O.J.1213, which was reported very susceptible to downy mildew disease in Australia, it seems to support strongly the view of dominance of the resistant gene (R) of Badila over the susceptible one.

In attempting to prove the hypothesis above mentioned, a series of other crosses as in Diagram II had been made and seedlings obtained from these crosses had been added to the farm for disease resistant trial this September on downy mildew under natural infection near Sinchu. This farm isolated from the sugarcane district is designed specially for the test.

Diagram II :



P. T. 52-11 performs very promisingly both in agronomic and disease-resistant characters. Further crosses we are planning to make in this winter. We are interested to see the response of those seedlings with 15, 25 and 30 chromosomes of Badila as far as the disease resistance to downy mildew is concerned.

Evidences from disease-resistant breeding showed clearly that the dosage effect of the resistant parent plants has determined mostly, if not all, the degree of disease resistance of the offsprings produced. Examples of F_1 seedlings having most visible characters of the susceptible parent plants to the particular disease of sugarcane are mostly susceptible to the respective disease also :

1. P. T. 46-144 and P. T. 46-256 of F.108 are susceptible to mosaic.
2. P. T. 48-3 and P. T. 50-707 of Co.290 are susceptible to leaf scorch disease of sugarcane.
3. P. T. 50-58 of P.T. 43-52 and P. T. 50-12 of P.O.J.2878 are very susceptible to downy mildew.

Using Badila as parent plant in crossing, we were disappointed first by the low sucrose content of most of its F_1 seedlings but used again for its high resistance to downy mildew disease of sugarcane. The same is Co.290, which has not been used in our crossing since 1950 owing to its being very susceptible to leaf scorch disease but used again last year due to its resistance to downy mildew. The success of hardcane breeding has lessened the menace from typhoon and emphasis has been put on disease resistance in our breeding programme so as to wipe out the most virulent diseases of sugarcane occurred in this island. The further idea we have in mind is to breed a special type of varieties of sugarcane which fits the requirements of the planters in cultivation making a satisfactory yield with less effort. Results from the studies on types of tillering of sugarcane (4,5,6,) revealed that the bowl-shaped and cup-shaped tillering varieties are especially good for extensive cultivation.

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DISCUSSION

Mr. Harbans Singh enquired how Mr. Dutt was able to assess the agronomic characters in seedlings propagated by the separation of individual tillers. Mr. Dutt replied that at that stage there was no selection, but only rapid multiplication, and the question of agronomic character did not arise.

Mr. E. G. Baber pointed out that the varieties of Australia mentioned in Mr. de Sornay's paper as ' pure lines ' were not so.

Mr. K. L. Khanna congratulated Dr. Tysdal on his paper. He furnished the information that as early as 1933, the Indian Council of Agricultural Research sponsored a project for the irradiation of sugarcane buds. In so far as producing superior mutants was concerned, this method was a failure. However, he felt that in the light of the results of Dr. Singleton's work in U.S.A., work on the possible production of mutations could be followed up in cane usefully.

Referring to Dr. Tysdal's paper, Dr. Raheja stated that P32 had been used to find out the uptake of phosphorous in crop plants and may be important more from the nutritional rather than the breeding point of view.

Group III

FLOWERING AND SEED PRODUCTION

Dr. S. J. P. Chilton presented the following two papers.

Paper

STUDIES ON THE FLOWERING OF SUGARCANE

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INTRODUCTION

A knowledge of the factors controlling the flowering of sugarcane would be of considerable value to the plant breeder bringing together varieties and strains of sugarcane into useful combinations. This is particularly true in Louisiana where natural flowering in the sugarcane growing area is very sporadic and of isolated occurrence.

The natural flowering of some of the commercial sugarcane varieties has been reported by Arceneaux and Hebert (1942) and by Abbott (1950). However, at Grand Isle, La., an Island in the Gulf of Mexico, the natural flowering of a considerable number of sugarcane varieties occurs, but temperatures are too low for the production of viable pollen. The use of techniques similar to those reported in South Africa by Brett (1947, 1949, 1950) has permitted the production of 225,000 seedlings from crosses and selfings in a three year period. This procedure, reported by Paliatseas, Steib, Dunckelman and Chilton (1954) utilizes sugarcane stalks which have set their floral initials, and after marcotting, are transferred into a green house to allow the maturation of the tassel and pollen production. Although this method permits making many desired crosses it is dependent on nature for the floral initiation and is affected by the low temperatures often occurring at Grand Isle, La.

A sugarcane breeding programme based on controlled flowering would avoid many of the difficulties encountered at present in the Louisiana sugarcane seed production programme.

LITERATURE

Allard (1938), Sartoris (1938), Allard and Evans (1941), and Lee and Lin (1951) have made attempts to induce flowering by adjusting the length of day. Similar attempts were made by Dutt (1932, 1943), Dutt and Yusuf (1945) and Yusuf (1950). The studies of the last investigators were successful in obtaining information on the relationship between photoperiodism and the time of flowering of sugarcane.

Vijayasaradhy and Narasimhan (1954) in extensive studies on the effect of the photoperiod on the induction of flowering in sugarcane have indicated that a day length of about 12 hours appeared to be critical for flowering and deviations of one or two hours day length in either direction greatly inhibited or suppressed flowering. They have also shown that if photoperiodic treatments of long or short days were given before floral initiation, flowering was inhibited. When the same treatments were given at the stage of floral initiation the flowering was delayed. Photoperiodic treatments at the post initiation stage had no effect on flowering. They successfully induced flowering in two non-flowering wild canes, *S. spontaneum*, Burma and *S. spontaneum* (Assam 301) by widely different treatments. However, the response to the treatments given was inconsistent.

With the exception of a report by Brandes and Matz (1939) no success in the induction of flowering has occurred with the *S. officinarum* varieties or the interspecific hybrids which include the commercial varieties and the parents used at present in the breeding programmes of the different countries.

In all the above studies of the photoperiodic induction of flowering of sugarcane a fixed day length treatment was used in each case. Chilton and Moreland (1954) have reported a twice repeated experiment where flowering with seven varieties of sugarcane having a high percentage of *Saccharum officinarum* in their parentage occurred. They applied a gradually diminishing photoperiodic light period on sugarcane plants.

In view of the results of this work in 1953 further tests on the experimental induction of flowering were made in the spring, summer and fall of 1954. The purpose of this paper is to give the results of these studies.

MATERIALS AND METHODS

Eighty-one varieties of sugarcane including 55 Canal Point and Florida varieties, seven varieties of *Saccharum officinarum*, five Australian varieties, six P.O.J. varieties, and two Barbados varieties were planted in October and November, 1953, in three gallon zinc galvanized buckets and were kept in the greenhouse until the middle of April, 1954. Beginning on May 21, 1954, and continuing through June 16, 1954, photoperiod treatments were started by placing the plants on trucks that rolled in and out of eight photoperiod houses following a carefully planned schedule. All treatments were started with a day length of 12 hours and 44 minutes plus the period from sunset to dark and the day lengths were reduced one minute a day. The experiment was continued for 80 to 85 days depending on the photoperiod house.

For many of the varieties only two pots containing one or two stalks were used. Many of the varieties did not grow well in the buckets and there seemed to be considerable zinc toxicity.

EXPERIMENTAL RESULTS

The first floral initial was found on August 1, 1954 and was probably present the last part of July. This was in the variety C.P. 48-126 which had been subjected to a light treatment from 12 hours and 44 minutes plus the period from sunset to dark to 11 hours and 29 minutes plus the period from sunset to dark. The last floral initial was found in Co. 290 on September 5, 1954, the range of light treatment being from 12 hours and 44 minutes plus the period from sunset to dark to 11 hours and 19 minutes plus the time from sunset to dark. The first flower emerged on August 25, 1954 and the last on February 25, 1955. Between August 1, 1954 and September 5, 1954, 32 more varieties of sugarcane had formed floral initials.

The number of varieties that flowered and their parentages are given in Table I. Seven of the varieties in the list had flowered under similar treatment in 1953. It may be seen from the Table that the vatieties that flowered were as follows : one variety of *Saccharum officinarum*, two hybrids of *S. officinarum* × *S. barberi*, two hybrids of *S. officinarum* x *S. spontaneum*, twenty-seven hybrids of *S. officinarum*, *S. spontaneum* and *S. barberi* and one hybrid which supposedly includes *S. officinarum*, *S. barberi*, *S. spontaneum* and *S. robustum*. One other variety, Co. 356 is supposed to be a hybrid between P.O.J. 2725 and Sorghum durra. If correct the parentage includes *S. officinarum*, *S. spontaneum* and *Sorghum durra*.

The six other varieties of *Saccharum officinarum*, the Hawaiian, P.O.J., some of the Australian and the two Barbados varieties did not flower.

DISCUSSION

It is difficult to conceive of three experiments covering two years and 34 varieties which would result in the chance flowering of sugarcane. It therefore seems that at least certain varieties of sugarcane can be induced to flower by a gradually shortening day length and flowering is a photoperiodic response. It is obvious that other environmental factors condition the sugarcane plant to respond photoperiodically otherwise all stalks of cane should flower in a field of the same variety. However, with the concept that if the necessary environmental and physiological factors are not satisfied the sugarcane stalk will not respond to the changing day length, then the problem of controlling the flowering of sugarcane resolves itself into a knowledge of these environmental and physiological factors.

SUMMARY

The results of photoperiodic tests in 1954 for inducing the flowering of certain varieties of sugarcane are given. Thirty-four varieties produced flowers.

TABLE I

LIST OF SUGAR VARIETIES WHICH PRODUCED FLOWERS IN 1953 AND 1954 AT BATON ROUGE, LOUISIANA

Variety	Parentage	Year flowered	
		1953	1954
	Saccharum officinarum		
28NG72—514	New Guinea importation		Yes
	Saccharum officinarum x *S. barberi*		
C.P.1161	P.O.J. 213 selfed 2 generations		Yes
C.P.1165	P.O.J. 213 selfed 2 generations		Yes
	Saccharum officinarum x *S. spontaneum*		
C.P.36—13[1]	P.O.J. 2725 x S. durra (?)	Yes	Yes
C.P.36—221[1]	P.O.J. 27 x S. durra (?)		Yes
	Saccharum officinarum x *S. barberi* x *S. spontaneum*		
Cl. 41—142	B. 35—9 x C.P. 27—108	Yes	Yes
Co. 290	Co. 221 x D. 74	Yes	Yes
C.P. 27—108	P.O.J. 2364 x C.P. 726		Yes
C.P.29—103	P.O.J. 2725 x C.P. 1165		Yes
C.P.29—116	P.O.J.2 725 x C.P. 1165	Yes	Yes
C.P.29—320	Co. 281 x C.P. 27—34		Yes
C.P.30—24	C.P. 27—22 x C.P. 1165		Yes
C.P.33—224	C.P. 27—139 x C.P. 31—432		Yes
C.P.34—79	P. 33—30 x C.P. 1161		Yes
C.P.34—120	Co. 281 x P.O.J. 2878	Yes	Yes
C.P.36—105	Co. 281 x C.P. 1165	Yes	Yes
C.P.38—34	Co. 421x C.P. 27—156		Yes
C.P.36—183	P.O.J. 2725 x C.P. 1165		Yes
C.P.36—187	P.O.J. 2725. x C.P. 1165		Yes
C.P.43—74	Co. 281 x C.P. 1165		Yes
C.P.44—101	Co. 281 x C.P. 1165	Yes	Yes
C.P.44—126	C.P. 33—229 x CP. 33—224		Yes
C.P.44—154	Co. 281 x U.S. 1694		Yes
C.P.44—156	Co. 281 x C.P. 27—108		Yes
C.P.48—96	P.O.J. 2725 x C.P. 1165		Yes
C.P.48—126	C.P. 36—105 x C.P. 38—34		Yes
C.P.49—49	C.P. 34—40 x C.P. 36—211		Yes
C.P.53—1	F. 36—819 x C.P. 48—126		Yes
C.P.53—97	Co. 41—142 x C.P. 43—74		Yes
C.P.53—98	F. 36—819 x C.P. 33—372		Yes
C.P.53—99	F. 36—819 x C.P. 46—173		Yes
Q.28	Co. 290 x Q. 1098		Yes
	Saccharum officinarum x *S. barberi* x *S. spontaneum* x *S. robustum*		
C.P.43—64	C.P. 36—138 x C.P. 27—108		Yes
	Saccharum officinarum x *S. spontaneum* x *Sorghum durra*		
Co.356	P.O.J. 2725 x Sorghum durra		Yes

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[1] One parent originally supposed to be *Sorghum durra* but seed probably due to apromixis (Sartoris, 1947).

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Paper

THE INDUCTION OF THE EMERGENCE OF THE INFLORESCENCE OF SUGARCANE

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INTRODUCTION

The emergence of the sugarcane inflorescence is a stage of flowering which marks the end of the development of the young inflorescence within the spindle or leaf sheath and the appearance of its visible floral buds.

Most of the accounts of the early work considered flowering of sugarcane as a single phenomenon and the conditions which determined flowering were examined as to their effect on flowering as a whole. However, flowering is not a single phenomenon but a chain of physiological processes which can be separated into four major stages. The conditions which determine the different stages are not always the same.

The major stages of flowering are: (1) floral initiation, (2) floral organization, (3) floral maturation, (4) emergence.

In tropical and subtropical areas with climatic conditions favcurable for natural flowering of sugarcane, the succession of the different stages of flowering cane is normal and uninterrupted. Once a variety of sugarcane sets floral primordia these develop and differentiate into full microscopic inflorescences which, after reaching full development, emerge. The time from initiation to emergence in those areas varies with the variety from four to six weeks.

In Louisiana, a subtropical area with mild fall and winter climate interrupted by periodic cold waves, floral initiation, at least in some varieties, takes place nearly every year in the sugarcane area. The emergence of the inflorescence takes place only in those years with above average fall and winter temperatures without freezes. This is an example of the interruption in the stages of flowering of sugarcane, indicating that temperature is one of the important factors for emergence.

There is another example of distinct separation between the different stages of flowering of sugarcane. At Grand Isle, a non-regular sugarcane area off the South Louisiana Coast, initiation and emergence of the sugarcane flower takes place almost every year.* Normal or above normal temperatures do not interrupt the stages of flowering. Below normal temperatures make possible the separation of stages of development. For instance, at Grand Isle most of the varieties which originated at Canal Point, Florida, set floral initials in the first half of October. They developed and emerged in November when temperatures were normal or above normal. When periodic cold waves occurred in November and interrupted the development of the inflorescence, the floral primordia set in October resumed growth late in January and emergence occurred in March, April and sometimes in May.

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* In 1950 emergence of flowering was interrupted by killing freezes.

There are varieties such as Co. 290, F. 36-819, Q. 28, C.P. 29-320, C.P. 29-103 and others in which the floral primordia are formed in the last part of October or the beginning of November. They remain dormant during the fall and winter and start developing at the end of January or February. The embryonic inflorescence reaches a stage of development of about 5-10 inches and either emerges (C.P. 29-103, C.P. 29-320) or remains depressed inside the spindle (Co. 290, F.36-819).

If the temperatures at Grand Isle were high enough for pollen production and viability would enable breeding of sugarcane under natural conditions, the problem of emergence would exist only for those varieties which do not naturally emerge. But minimum temperatures during fall and winter are too low for pollen production. To insure viable pollen production a modification of the technique reported in South Africa by Brett (1950) is used. This technique involves airlayering of selected sugarcanes and transferring these to the greenhouse where a higher temperature prevails. Moving selected sugarcane stalks into the greenhouse just after floral setting caused a depression of flower emergence and the losses were high Eventually techniques were found by which the percentage of emergence was increased. It is the purpose of this paper to describe these techniques and to give the results obtained.

REVIEW OF LITERATURE

Most of the writers do not mention stages in flowering and their attempts to find factors that control flowering apparently refer to floral initiation, which is the most important stage of flowering. Length of day adjustments used by Dutt (1932-1943), Dutt and Yusuf (1945), Allard (1938), Sartoris (1928), Allard and Evans (1941), Lee and Lin (1951), Brandes and Matz (1939), and Chilton and Moreland (1954), apparently affect floral initiation.

Vijayasaradhy and Narasimhan (1954) distinguished stages in the development of the inflorescence of sugarcane and revealed that early and late flowering varieties set floral initials at the same time, the only difference being in the rate of growth of the inflorescence between varieties. They reported that normal day length (12 hours) is critical for flowering of sugarcane. Extra light or dark treatments given before the initiation stage inhibited flowering, extra light or dark given during the initiation stage suppressed flowering and the same treatment given after the initiation stage had no effect. This indicated clearly that the factors affecting initiation were not the same as the factors affecting emergence.

McMartin (1949) reported differences in the amount of flowering in different varieties of sugarcane. Some rarely flowered, some formed flowers which did not emerge, such as Co. 290, while others, such as N.Co. 310 flowered profusely.

Brett, (1950) in trying to develop techniques to preserve canes in the greenhouse, reported difficulties in emergence of the inflorescence when canes were preserved in acid solution. These difficulties were overcome by using the rooting technique. The variety Co. 290, which did not emerge naturally, emerged under greenhouse conditions.

Mention of suppression in flower emergence under greenhouse conditions was made by Bourne (1938). He planted a stool of P.O.J. 2725 in the greenhouse in October, apparently after initiation. No emergence occurred. In March it was moved to the outside and it flowered.

Some factors that have a regulatory effect on initiation have an indirect effect on emergence. Heavy rainfall during the growing season has increased the percentage of flowering by increasing the percentage of floral initiation. Baretto (1934), noticed acceleration of flowering of sugarcane in years of heavy rainfall. Sartoris and Belcher (1949) reported an acceleration of flowering of sugarcane during the fall of 1947 as a result of high fall temperatures and flooding. Kerr (1940) observed a reduction in the percentage of flowering of sugarcane as a result of the application of nitrogen. DeAlmeida, Valsecchi and Gomes (1946) reported that application of potash led to an acceleration of flowering, while the application of nitrate either impeded or prevented flowering. Vijayasaradhy and Narasimhan (1954) showed that irrigation had an increasing effect on flowering while fertilizers had no effect. Morimasa Yamasaki and Hiroshioda (1938) proved that the flowering percentage of sugarcane increased on the edges of the field facing west, while southern exposures produced the minimum flowering percentage.

MATERIAL AND METHODS

To determine whether the date of transferrence to the greenhouse of the selected and rooted sugarcane stalks had any effect on the emergence of their flowers, the following experiment was conducted in the 1952-53 season. Eight hundred and fifteen sugarcane stalks involving 17 Canal Point varieties, two Coimbatore varieties, one South African variety and one Florida variety were rooted in stovepipe tubes which had been filled with a mixture of 3/4 muck soil and 1/4 pure sand. Four dates of rooting were used : October 1, October 15, November 1, and November 15. On the first date a group of 173 stalks were rooted ; in the second, third, and fourth dates respectively 158, 183, and 301 stalks were rooted. The first group of cane stalks was transferred to the greenhouse on November 1, the second, third and fourth on November 15, December 1, and December 15, respectively. The stalks in the tubes were watered daily and were kept in the greenhouse under controlled temperature conditions between 75°F. and 80°F.

The number of stalks which flowered per variety and per transferred group and the percentage of flowering was recorded.

A second experiment was conducted in 1952-53 to determine whether or not exposure of the sugarcane stalks to sunlight in the greenhouse had any effect on flower emergence. One hundred stalks involving five varieties with 20 stalks per variety were selected and rooted in stovepipes filled with the mixture indicated above. The rooting was made in the field in the middle of October, after floral initiation. In the middle of November the rooted stalks were transferred to the greenhouse and four exposures were given with 25 stalks, five of each variety, facing north, 25 facing south, 25 facing east, and 25 facing west. The number of flowers emerged per variety and exposure was recorded.

There were some varieties which failed to emerge regardless of any treatment. Some others failed to emerge only when the stalks were too crowded in the greenhouse and they did not receive a sufficient amount of light. In the above cases the flower or inflorescence inside the leaf sheath was alive and completely developed (boenting stage).

The following technique was applied to force the emergence of such flowers. The sheath of the short leaf (flag) was lightly scored 3″ to 4″ below the ligules, carefully split and removed, exposing to light the top part of the inflorescence. The exposed part of the inflorescence which was white at the time of exposure turned pink in three or four days and started to project further until the inflorescence completely emerged. In the event of restriction in the outward movement of the inflorescence the above process was repeated two to three times, allowing the exposure of a longer part of the inflorescence at a time until the inflorescence was completely exposed. Such practice however was seldom necessary.

EXPERIMENTAL RESULTS

Effect of Date of Transfer of the Rooted Sugarcane Stalks to the Greenhuose on Flower Emergence. The effects of early and late transfer of the selected and rooted sugarcane stalks to the greenhouse on flower emergence are shown in Table I. The transfer of the selected stalks to the greenhouse was always made after floral initiation. As is shown in Table I, the percentages of flower emergence in the first andsecond groups were very low, while the percentages in the third and fourth groups were considerably higher.

Effect of Exposure to Sunlight of Sugarcane Stalks on Flower Emergence. The effect on emergence from the canes which were transferred to the greenhouse and exposed to sunlight is shown in Table II. Sugarcane stalks facing west and south emerged more flowers than those facing east and north. This was effected because the canes which were facing south and west received more sunlight than those facing north and east.

Highly significant differences were found in the number of inflorescences emerged from cane stalks of different varieties at different exposures.

Analysis of variance is given in Table III.

TABLE I

EFFECT OF DATE OF TRANSFERRING INTO THE GREENHOUSE OF EARLY INTERMEDIATE AND LATE ROOTED SUGARCANE STALKS ON FLOWERING IN SOME VARIETIES TESTED AT GRANDISLE, LA. IN 1952

Variety	No. of cane stalks* rooted and transferred				Total No. trans- ferred	No. of arrows				Total No. flowered	Percentage of flowering			
	Group					Group					Group			
	1	2	3	4		1	2	3	4		1	2	3	4
Co. 281 ...	10	10	20	25	65	2	2	15	19	38	20·0	20·0	75·0	76·0
Co. 356 ...	5	5	5	5	20	0	0	2	4	6	0·0	0·0	40·0	80·0
N. Co. 310 ...	3	3	3	6	15	0	2	1	4	7	0·0	66·6	33·3	66·6
Cl. 41-142 ...	5	5	5	10	25	1	0	1	4	6	20·0	0·0	20·0	40·0
C.P. 27-108 ...	10	10	10	10	40	0	0	1	3	4	0·0	0·0	10·0	30·0
C.P. 29-103 ...	10	10	15	15	50	0	0	1	2	3	0·0	0·0	6·6	13·6
C.P. 29-116 ...	10	5	5	20	40	4	2	5	18	29	40·0	40·0	100·0	90·0
C.P. 29-320 ...	10	10	10	25	55	0	0	2	5	7	0·0	0·0	20·0	20·0
C.P. 30-24 ...	5	5	5	15	30	2	2	2	10	16	40·0	40·0	40·0	66·6
C.P. 33-224 ...	10	10	10	15	45	0	0	1	1	2	0·0	0·0	10·0	6·6
C.P. 33-372 ...	5	5	5	10	25	0	1	4	8	13	0·0	20·0	80·0	80·0
C.P. 34-120 ...	20	20	20	40	100	5	13	15	32	65	20·0	65·0	75·0	80·0
C.P. 36-105 ...	15	15	20	25	75	5	2	15	22	44	33·3	13·3	75·0	88·0
C.P. 36-156 ...	2	2	2	4	10	0	0	1	2	3	0·0	0·0	50·0	50·0
C.P. 38-34 ...	10	10	10	15	45	2	2	1	5	10	20·0	20·0	10·0	33·3
C.P. 43-64 ...	15	10	15	15	55	0	0	0	2	2	0·0	0·0	0·0	13·3
C.P. 43-74 ...	10	5	5	15	35	0	0	3	9	12	0·0	0·0	60·0	60·0
C.P. 44-101 ...	10	10	10	10	40	6	8	0	0	14	60·0	80·0	0·0	0·0
C.P. 44-155 ...	5	5	5	15	30	0	0	0	7	7	0·0	0·0	0·0	46·6
C.P. 45-155 ...	1	1	1	2	5	0	0	0	2	2	0·0	0·0	0·0	100·0
C.P. 48-106 ...	2	2	2	4	10	0	0	1	3	4	0·0	0·0	50·0	75·0
Total ...	173	158	183	301	815	27	34	71	162	294				

* Group 1 was rooted Oct. 1, transferred Nov. 1 ; Group 2, rooted Oct. 15, transferred Nov. 15; Group 3, rooted Nov. 1, transferred Dec. 1 ; Group 4, rooted Nov. 15, transferred Dec. 15.

TABLE II

EFFECT OF THE EXPOSURE TO SUNLIGHT ON FLOWERING OF SUGARCANE STALKS OF FIVE VARIETIES INSIDE THE GREENHOUSE AT GRAND ISLE LA. IN 1952

Variety	No. of sugarcane stalks facing					No. of arrows emerged from stalks facing				
	North	East	South	West	Total	North	East	South	West	Total
C.P. 29-116	5	5	5	5	20	1	2	3	5	11
C.P. 30-24	5	5	5	5	20	1	1	2	3	7
C.P. 34-120	5	5	5	5	20	2	2	4	5	13
C.P. 36-105	5	5	5	5	20	1	2	3	5	11
C.P. 44-101	5	5	5	5	20	1	2	3	4	10
TOTAL	25	25	25	25	100	6	9	15	22	52

TABLE III

SUMMARY OF ANALYSIS OF VARIANCE OF THE NUMBER OF SUGARCANE ARROWS EMERGED FROM CANES IN THE GREENHOUSE AT DIFFERENT EXPOSURES TO SUNLIGHT

Variance due to	Degrees of freedom	Sum of squares	Mean square
Varieties	4	4.8	1.20**
Exposures	3	30.0	10.00**
Error	12	2.0	0.16
Total	19	36.8	

**Significant at one percent

THE EFFECT OF DISSECTION ON EMERGENCE

Eight varieties involving ten stalks per variety were selected in the greenhouse after they had reached the short leaf stage (flag). The inflorescences within the leaf sheath, though alive, failed to emerge naturally. Five of these were split open and the top part of the leaf sheath was removed. The rest were left unsplit. The results are shown in Table IV.

TABLE IV

EFFECT OF DISSECTION ON EMERGENCE OF SUGARCANE INFLORESCENCES AT GRAND ISLE, LOUISIANA, 1953

Variety	No. Dissected Tops	No. non-dissected Tops	Percent of emerged inflorescence	
			Dissected Tops	Non-dissected Tops
C.P. 29-103	5	5	80	0
C.P. 29-320	5	5	60	20
C.P. 33-224	5	5	80	20
C.P. 38-34	5	5	80	0
C.P. 43-64	5	5	100	0
C.P. 43-74	5	5	100	20
C.P. 48-126	5	5	60	20
Co. 290	5	5	40	0

DISCUSSION

The emergence of the sugarcane inflorescence was controlled by several environmental conditions of which temperature, light intensity and light quality were the most important.

The differences in the percentages of flower emergence at the different rates of transfer might be explained by the following approach. When the transfer was early the stage of development of the embryonic flower within the spindle was small. Since floral initiation was determined by specific (photoperiodic) stimuli an obvious question was whether or not these stimuli had some part in the further development of the flower. Much evidence indicated that they did have, for at least some time after initiation.

The transfer of sugarcane stalks to the greenhouse at the early stage of the development of the inflorescence withheld those stimuli which controlled the further flower development and resulted in lower percentages of flower emergence. When the transfer of sugarcane was made to greenhouse at a later stage of the flower development, no interruption in the development of the flower occurred by the withholding of the floral initiation stimuli.

The effect of exposure to sunlight of sugarcane stalks on flower emergence indicated that intensity of light was a factor which affected flower emergence. Since plants in the south and west exposures received more light, this resulted in a higher percentage of emergence. The failure of some inflorescences to emerge was due to failure of satisfaction of the physiological factors which controlled emergence.

When there were mechanical barriers, such as the sclerenchymatisation of the tissue around the vascular bundles or an overtwisting of the spindle, emergence was prevented. Dissection relieved the situation and emergence followed.

SUMMARY

The emergence of sugarcane inflorescences is controlled by environmental factors, such as temperature, light intensity and light quality. The different stages of development of the inflorescences conditioned the responses which were brought about by different sets of environmental factors. Plants in the later stages of development responded more readily to the environmental changes which were brought about by transfer to the greenhouse. Exposure to sunlight resulted in an acceleration of flower emergence. Dissection of the top part of the spindle facilitated the emergence under conditions which had restricted further development.

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In the absence of the author the following paper was presented by Mr. E. G. Baber.

Paper

THE APPARENT INFLUENCE OF TEMPERATURE DURING THE CANE BREEDING SEASON ON THE FERTILITY OF THE FUZZ PRODUCED

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The influence of temperature on the production of fertile pollen in sugarcane flowers had been demonstrated clearly by Brett (1) in sub-tropical South Africa. Many varieties of sugar cane produced much more fertile pollen when the arrow bearing stalks were removed from the fields and cultured inside a glass house, by various means, at a minimum temperature of 70°F., which was considerably higher than the field temperature.

This influence has been confirmed in Louisiana by Paliatseas and Chilton (5) and at Canal Point, Florida, by Grassl and Belcher (4). At the last mentioned station (27° North Latitude) an average minimum temperature of 59°F. during the flowering season was found unsuitable for pollen formation when crosses were set up in open positions.

Not only does temperature influence the formation of fertile pollen, but Brett (2) has further shown that ovule fertility was appreciably increased in the case of certain seed bearing parent varieties at Mount Edgecombe, Natal, by artificially increasing the temperature during arrow development of the plants being studied.

In view of the above experience at sub-tropical sugarcane breeding stations, it will no doubt be of interest to record briefly some observations on the apparent influence of temperature on fertility at the C. S. R. Co.'s sugarcane breeding station at Macknade, Queensland, which, at approximately 18° 35′ South Latitude, lies within the tropical belt.

At this station the normal time for arrowing in the main breeding varieties is late May to the end of July ; sometimes late arrows occur early in August. Crosses are set up in open atmospheric positions by means of the sulphurous-phosphoric acids solution method of preserving the arrows. No lanterns are used, but the crosses are arranged, as far as possible, so that advantage is taken of the protecting canopy (often semi shade) of shrubs and trees.

Under these conditions much seasonal variation in the fertility of the arrow "fuzz" produced has occurred. Consideration has been given to what are considered to be the main factors limiting the success of a seasonal breeding programme and these may be summarised as follows :—

1. Light arrowing (numerous desired parent varieties fail to arrow).

2. Low temperatures during arrowing period inhibiting the production of fertile pollen and general fertility.
3. Persistent rainfall during arrowing period militating against optimum another dehiscence.
4. Drought during arrowing period causing abortive arrowing.
5. Strong drying winds causing the dispersal of pollen and damaging arrows.

Varying combinations of these limiting factors are experienced from year to year, sometimes only one, but often a combination of several of them, occur during a season. Seasons when the majority of these factors have been absent have been the most successful, while the persistent operation of one, or a combination of several of them, have caused poor results.

There are indications, however, that low temperatures during the arrowing period, may be the most important of the above factors and it is interesting that the average minimum temperature during May and June, the main breeding period, frequently falls below the 59°F. quoted for Canal Point (4).

TABLE I

Year	Temperature °F Average May	June	July	Lowest Reading May, June or July	Remarks
1945	62	61	59	44	Male arrows produced much pollen ; many females showed a high degree of fertility ; high degree of self fertility.
1946	63	54	54	42	Conditions less favourable than in 1945 : pollen less abundant. Some of the earlier female parents showed good fertility.
1947	65	60	55	49	Favourable crossing season : arrowing season shorter than usual—few young arrows after the end of June. Good pollen abundance except in last half of July.
1948	63	56	58	43	Arrowing early and profuse. Late arrows generally less fertile than earlier ones.
1949	62	54	53	41	Season generally poor for pollen abundance.
1950	62	57	64	45	Fertility generally poor persistent rainfall during arrowing period.
1951	62	56	56	44	Droughty season-arrowing light, pollen abundance and fertility below normal.
1952	64	56	58	46	Pollen formation and fertility below normal.
1953	58	56	56	44	Pollen formation and fertility in fuzz poor.
1954	64	59	58	48	A good season for pollen formation and fertility.
1955	65	62	61	51	Pollen formation and fertility above normal—a good breeding season.

In Table I, the average minimum temperatures at Macknade for the months of May, June and July and the lowest recorded temperature for that period, are compared with brief remarks on the results of the breeding programmes carried out during each of the years 1945 to 1955 inclusive. These generally indicate that the years of low minimum temperatures during the arrowing periods are those when fertility in the cane arrows has been poor.

It has been stated elsewhere (3) that the varieties Korpi, Badila, Oramboo and Q.813 have been prominent in the genealogy of many of the high quality seedlings produced at Macknade. These are noble canes of high sucrose. None of them has shown high fertility as a parent ; they produce little or no pollen in most arrowing seasons and Korpi, perhaps the most important of the group, consistently shows poor fertility. They are late arrowers and it is likely that the lower temperatures experienced during the latter portion of the breeding season could account for their comparatively poor fertility at this station.

SUMMARY

That temperature during the flowering period has a distinct bearing on the fertility of sugarcane flowers in sub-tropical countries has been clearly demonstrated by sugarcane breeders in South Africa, Louisiana and Florida.

At the C.S.R. Co.'s sugarcane breeding station at Macknade, Queensland, situated in the tropics at slightly more than 18° South Latitude, there have also been indications of the limiting influence on fertility of low temperatures.

The factors considered most likely to limit the success of a seasonal breeding programme at Macknade, where crosses between sugarcane varieties are carried out in open atmospheric conditions, are discussed in this paper and it is concluded that there are indications that low temperatures during the breeding season may be the most important of these factors.

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DISCUSSION

Mr. Panje enquired from Dr. Chilton what the basis was for the statement in his paper that plants in the eastern part of the photoperiod house received more light than those in the western part.

Dr. Chilton explained that there was a group of trees in the west and regretted the omission of this explanation in the paper.

Mr. Dutt gave the information that some success had been achieved at Coimbatore in synchronising the flowering period of early and late flowering varieties. He further stated that due to certain climatic conditions at Taliparamba in West Coast (which ıeceived a rainfall of 150 inches per annum) one or two varieties that had flowered very rarely at Coimbatore flowered there and the shy flowerers of Coimbatore were profusely flowering at Taliparamba.

Dr. P. C. Raheja wanted to know from Dr. Chilton whether the thermo or photo phase was important for floral initiation. Dr. Chilton replied that the latter which he thought was identical with "photoperiod" was the more important.

Group IV

GENETICS

In the absence of the author the following paper was presented by Dr. A. J. Mangelsdorf.

THE INHERITANCE OF HAIRINESS IN SUGARCANE

J.C. Skinner

Buerau of Sugar Experiment Stations, Queensland, Australia

INTRODUCTION

Little is known about the inheritance of sugarcane characters. Some workers have noted the dominant relations of characters in crosses between *Saccharum* species (for example, Chen[3]) and between varieties of sugarcane. The most comprehensive account of inheritance in sugarcane appears to be that by Venkatraman[10] who published data indicating inheritance of various characters. The characters studied included (a) general characters of the plant in the field, (b) certain morphological characters of the leaf and cane, (c) physiological and habit characters of the root, (d) percentage of sucrose in juice and (e) susceptibility to smut. The data demonstrate an influence of both parents on these characters, and segregation ratios are given for some characters. The only hair group mentioned by Venkatraman is the circlet of hairs at the nodes and immediately beneath the bases of the leaf sheaths (Jeswiet group 59). Various segregations were observed when P.O.J.213 was crossed with selected male parents. Examination of these ratios indicates that they might be explained on a simple genetical basis but the data are not sufficient for the formulation of a definite conclusion.

Stevenson[8] studied variation in sugarcane seedling populations in comparison with that in clonal material. He obtained an estimate of differences in genetical variation between populations from different parentages. The same author[9] gave percent sucrose and weight distribution curves for populations of seedlings from certain selfs and crosses. His work gives some indication of the contribution of genotype and environment to the phenotypic variation shown by seedling populations.

The sugarcane varieties grown today are mainly complex polyploids or aneuploids. Most writers have concluded that inheritance will follow a complicated pattern, even for characters which show simple Mendelian inheritance in diploid species. So far as I am aware simple Mendelian inheritance has not previously been demonstrated for any sugarcane character.

During 1953 numerous characters were examined in families of commercial seedlings growing on the Northern Station of the Queensland Bureau of Sugar Experiment Stations. Certain hair group characters were considered most promising for genetical analysis because they differed markedly in different varieties and they were not greatly influenced by variations in the environment.

MATERIAL AND METHODS

This study is concerned with the inheritance of certain hair groups of the leaf sheath. These hair groups have been defined and numbered by Jeswiet[5], and have been further described by Artschwager[1].

JESWIET GROUP 57

This hair group covers the outer (dorsal) surface of the sheath to a greater or lesser degree. It is found in many cane varieties.

JESWIET GROUP 60

This consists of two hair groups on the sides of the leaf sheath. Artschwager notes that these lateral patches often occur together with the dorsal patch, but they are found in fewer varieties. The arrangement on a given sheath is often asymetrical. The lateral patches are practically always inserted high and usually terminate immediately below the dewlaps.

JESWIET GROUP 56

This group consists of a fringe of hairs on the upper part of the sheath margin. It is strongly developed in many wild canes, lacking in most noble canes, and weakly developed in some hybrids between *Saccharum officinarum* and *Saccharum spontaneum*.

The parent varieties used in this study are described in Table 1.

TABLE I

CHARACTERISTICS OF PARENT VARIETIES

Variety	Male or Female	1953 Pollen		Jeswiet Hair Groups		
		%viable	Abundance	56	57	60
A. 130	male	2—5	abundant		med.*	sl.
Co. 301	male	50	abundant	abs.	v. sl.	ex. sl.
Co. 331	male	30	abundant	abs.	abs.	abs.
Co. 419	female	0	sparse	v. sl.	+	+
E. 281	male	30—50	abundant		+	sl.
Eros	male	15—30	medium	v. sl.	+	+
Pompey	male	15—30	average	abs.	med.	sl.
38 S. N. 4305	female	0	abundant	abs.	med.	med.

*Characters in all tables are classified as absent (abs.), extremely slight (ex. sl.), very slight (v. sl.), slight (sl.), medium (med.), abundant (+), and very abundant (++).

The pollen viabilities indicate that no self-pollination occurred in the female varieties Co. 419 and 38 S.N.4305.

Pollination, seed handling and transplanting followed the general procedure described by Hughes[4]. This procedure ensures a high degree of accuracy in producing commercial seedlings. For genetical purposes extreme accuracy is required. The methods are not completely satisfactory for this purpose but it is unlikely that the results were significantly affected by technique. One hybrid was detected in the seedlings produced by self-pollinating E.281. The self-pollinated families were uniform for a number of distinguishing characters and it is unlikely that any other hybrids escaped detection. Contamination by foreign pollen was much more probable in self-pollinated as compared with cross-pollinated families because seed setting was poor in the selfed varieties and the stigmas remained receptive for long periods.

When the seedling families were transplanted to the field the parent varieties were planted at regular intervals amongst them. These parents provided a check on variation in characters in different parts of the field.

All characters were determined at maturity. Each character showed a small amount of environmental variation and several stalks were examined in each stool to obtain a reliable evaluation of each character. In rare instances seedlings had less than four stalks or were not suitable for examination for other reasons. The characters of such seedlings were not recorded. Despite these precautions poor penetrance of characters may have biased the results slightly. Each seedling was identified by its position in the field. Numerous seedlings were re-examined at random and the determinations made for each character were found to agree closely with the original determinations. It is unlikely that the results were affected by errors of classification.

RESULTS

1. GROUP 56.

Segregations for group 56 are shown for all crosses in Table II.

TABLE II

SEGREGATION OF HAIR GROUP 56

Cross	Abs.	Ex. Sl.	V. sl.	Sl.	Med.	+	++	Total	Pres.	Abs.	Theoretical ratio Pres : Abs.	P
Co. 419 × Co. 331 V. sl. Abs.	91	5	5	11	8	5		125	34	91	1 : 3	.5—.7
38 S.N. 4305 × Co. 331 Abs. Abs.	106	6	3	7	5	5		132	26	106	1 : 3	.1—.2
Co. 419 × Eros V. sl. V.sl.	131	2	3	115	5	2		258	127	131	1 : 1	.8—.9
Co. 419 × Pompey V. sl. Abs.	8	1			3	1	3	16	8	8	1 : 1	1.0
Co. 419 × Co. 301 V. sl. Abs.	22	1	3	3	3			32	10	22	1 : 3	.3—.5

If the character was present it varied from extremely slight to abundant. The results indicate that the segregation of presence versus absence of the character was determined by a single major gene in two crosses and by two major genes in the other three crosses, the genes giving simple diploid segregation ratios. The possible genetical constitution of each parent is shown in Table IV.

2. GROUP 60.

Segregations for group 60 are shown for all crosses in Table III.

TABLE III

SEGREGATION OF HAIR GROUP 60

Cross	Abs.	Ex. sl.	V. sl.	Sl.	Med.	+	++	Total	Pres.	Abs.	Theoretical Ratio Pres. Abs.	P
A. 130 self Sl.	2			1	1	1		5	3	2	3 : 1	.7—.8
E. 281 self Sl.	6		2	19		1		28	22	6	3 : 1	.5—.7
Co. 419 × Co. 331 + abs.	95	4	5	15	9	1		129	34	95	1 : 3	.7—.8
38 S.N.4305× Co. 331 Med. abs.	108	5	3	10	6			132	24	108	1 : 3	.1—.05
Co. 419 × Eros + +	33	17	25	44	67	48	24	258	225	33	7 : 1	.8—.9
Co. 419 × Pompey + sl.	8				3	5		16	8	8	9 : 7	.5—.7
Co. 419 × Co. 301 + ex. sl.	11	5	5	5	6	1		33	22	11	9 : 7	.2—.3

The general picture is similar to group 56. The presence or absence of the character appears to be determined by a single major gene in the two selfs, by two major genes in three crosses, and by three major genes in two crosses. The possible genetical constitution of each parent is shown in Table IV.

TABLE IV

POSSIBLE GENETICAL CONSTITUTION OF PARENT VARIETIES FOR HAIR GROUPS 56 AND 60

Variety	Group 56	Group 60
A. 130		ee Ff GG(ii)
Co. 301	aa bb CC dd(i)	ee Ff Gg
Co. 331	aa bb CC dd	ee ff gg
Co. 419	Aa Bb CC dd	Ee ff Gg
E. 281		ee Ff GG
Eros	aa BB CC DD	Ee Ff GG
Pompey	aa BB CC dd	ee Ff Gg
38 S.N. 4305	Aa Bb cc dd	Ee ff Gg

(i) Group 56 is present if dominant genes A, B and C are all present as homozygotes or heterozygotes. If A, B or C is absent the hair group does not occur unless DD is present in a homozygous dominant condition.

(ii) Group 60. E or F causes presence of group 60 if G is also present.
60 present : E F G, e F G, E f G.
60 absent : E F g, e f G, e f g, etc.

No particular significance is attached to the genetical constitutions given for groups 56 and 60 and they may require modification when more data are obtained. The genetical constitutions are indicated by alphabetical letters. These letters have been used for convenience and are not regarded as permanent symbols for the characters.

3. GROUP 57.

Segregations for group 57 are shown for all crosses in Table V.

TABLE V

SEGREGATION OF HAIR GROUP 57

Cross	Abs.	Ex. Sl.	V. Sl.	Sl.	Med.	+	++	+++	Total	Pres.	Abs.
Co.419 × Co. 331 + abs.	12	11	2	63	41				129	117	12
A. 130 self Med.		1	1	3		1			6	6	0
E. 281 self +			1	2	4	21			28	28	0
38 S.N. 4305 × Co. 331 Med. abs.	27	25	10	44	25	1			132	105	27
Co. 419 × Eros + +	3	2	5	73	78	86	11	1	259	256	3
Co. 419 × Pompey + med.	2	2		2	2	8			16	14	2
Co. 419 × Co. 301 + V.sl.	5	1	1	15	10	1			33	28	5

There is no clear indication that this character is determined by major genes, nor is the possibility excluded.

ASSOCIATION BETWEEN CHARACTERS

1. Groups 56 and 60 :—In the cross Co.419×Co.331 both groups appear to be segregating in the ratio of 1 present : 3 absent. If these characters are completely independent in inheritance they will segregate in the ratio of 1 (bore present) : 3 (56 pres., 60 abs.) : 3 (56 abs., 60 pres.) : 9 (both absent). If they are linked in inheritance there will be an excess of the parental types and a deficiency of the non-parental types. The combined segregations are shown in Table VI.

TABLE VI

SEGREGATION OF HAIR GROUPS 56 AND 60 IN THE CROSS Co. 419 × Co.331

Class	Observed (O)	Expected (E) 1 : 3 : 3 : 9	O—E	$X^2 = \frac{(O-E)^2}{E}$
Both absent	67	70.2	—3.2	0.15
56 pres., 60 abs.	25	23.4	+1.6	0.11
56 abs., 60 pres.	24	23.4	+0.6	0.02
Both present	9	7.8	+1.2	0.18
Total	125	124.8	+0.2	0.46

Degrees of freedom=3. P=.9—.95.

There is a close agreement between the observed values and the values expected on the hypothesis that the characters are segregating in a ratio of 1 : 3 : 3 : 9. In the cross Co.419 × Co.331 groups 56 and 60 therefore appear to be determined by major genes which are completely independent in inheritance.

Segregations for both characters in all crosses are shown in Table VII.

TABLE VII

SEGREGATIONS OF HAIR GROUPS 56 AND 60 IN ALL CROSSES

Cross	Observed Segregations Both absent	56 abs. 60 pres.	56 pres. 60 abs.	Both present	Total	Linkage Chi-Square(i)	P
Co. 419 × Co. 331	67	24	25	9	125	0	1.0
38 S.N.4305 × Co. 331	89	17	18	8	132	2.8	.1—.05
Co. 419 × Eros	15	116	19	107	257	0.56	.3—.5
Co. 419 × Pompey(ii)	6	2	2	6	16	2.25	.1—.2
Co. 419 × Co. 301	7	15	4	6	32	0.16	.5—.7

(i) The linkage chi-square was calculated from the group totals so that one degree of freedom is available to determine the probability value.

(ii) In the cross Co.419 × Pompey, Yates' correction was used because the number expected in each class was less than 5.

In no case is the probability less than 0.05 so the results are in agreement with the hypothesis that groups 56 and 60 are determined by major genes which are independent in their inheritance.

2. Groups 57 and 56 :—Because of uncertainty regarding the genetical factors determining group 57 it is not considered desirable to present the combined segregations of 57 vs. 56 and 57 vs. 60 in an abbreviated form. As an alternative the detailed segregations are presented for the crosses Co.419 × Co.331 and Co. 419 × Eros. The other crosses gave similar results. The segregation of groups 57 and 56 is shown for these crosses in Table VIII.

TABLE VIII

SEGREGATION OF HAIR GROUPS 57 AND 56

Group 57	Cross : Co. 419 × Co. 331						Cross : Co.419 × Eros					
	Group 56						Group 56					
	Abs.	Ex. Sl.	V. Sl.	Sl.	Med.	+	Abs.	Ex. Sl.	V. Sl.	Sl.	Med.	+
+ +							4			7		
+							39	1	2	43	1	
Med.	30	1	2	3	3	1	45		1	29	2	1
Sl.	45	2	2	3	5	3	40	2		27	2	1
V. sl.				2			1			4		
Ex. sl.	9	1		1		1				2		
Abs.	8	2	2				2			1		

There appears to be no association between groups 57 and 56.

3. Groups 57 and 60 :—The segregations of groups 57 and 60 is shown in Table IX.

TABLE IX

SEGREGATION OF HAIR GROUPS 57 AND 60

	Cross : Co.419 × Co.331 Group 60						Cross : Co. 419 × Eros. Group 60						
Group 57	Abs.	Ex. Sl.	V. Sl.	Sl.	Med.	+	Abs.	Ex. Sl.	V. Sl.	Sl.	Med.	+	++
++													12
+							2	1	3	6	21	41	12
Med.	17	1	3	12	8		7	4	8	18	35	6	
Sl.	53	3	2	3	1	1	19	9	13	19	11	1	
V. sl.	2						2	1	2				
Ex. sl.	11						1	1					
Abs.	12						3						

There is a definite association between these groups. Group 60 does not occur unless group 57 is also present. If group 57 is present group 60 ranges from absent to abundant in different individuals, but there also appears to be a positive correlation between quantitative development of groups 57 and 60. When group 60 is absent group 57 ranges from absent to strongly developed.

DISCUSSION

The chief value of this work is considered to be the strong indication that the presence or absence of Jeswiet's hair groups 56 and 60 is determined by a small number of major genes. The results are in agreement with the hypotheses that the segregation of presence versus absence of group 56 is determined by one or two major genes in different crosses, that the presence or absence of group 60 is determined by 1, 2 or 3 major genes in different crosses, that the genes determining the two groups are completely independent in inheritance, and that the genes give simple diploid segregation ratios. The possibility of polyploid segregation is not completely excluded but it is improbable. For example in crosses Co.419 × Co.331 and Co.419 × Co.301, group 56 gives segregations which agree satisfactorily with a 1 : 3 but not with a 1 : 5 ratio, the latter being a typical single gene auto-tetraploid ratio. Single genes in auto-tetraploids do not always segregate in a simple 1 : 5 ratio so the possibility of polyploid segregation cannot be completely excluded.

The occurrence of diploid segregation ratios in an old polyploid such as *Saccharum officinarum* is not surprising. It is now known that a new autopolyploid may gradually shift to a diploid behaviour both genetically and cytologically. Within a few generations the chromosomes of an autopolyploid may undergo differentiation because of structural changes such as inversions and interchanges and the genes may diverge by mutation and hybridisation. This leads to a change from multivalent to a bivalent type of synapsis, and from autopolyploid to diploid segregation ratios. Probably this process has occurred during the evolution of *Saccharum officinarum*. Cytologically this species behaves as a diploid, producing only bivalents at meiosis (Li *et al*[6]). However, most of the parent varieties used in this study are the result of nobilization following crosses between *Saccharum officinarum* and *S. spontaneum*. In the first cross and the second generation backcross chromosome doubling on the female side occurs in the *S. officinarum* chromosome complement (Bremer[2]). The parent varieties would therefore be recently autopolyploid for many chromosomes. The occurrence of diploid segregation ratios when these varieties are crossed would indicate that the particular chromosomes carrying the hair group genes are behaving in a diploid, not in an autopolyploid or haploid manner. Cytological studies have shown that many chromosomes in varieties such as these do show diploid behaviour. For example, P.O.J. 2725 ($2N = 107$) produced 9-23 univalents and 42-49 bivalents, higher multivalents being absent at meiosis (Li *et al*[6]). Genes located on chromosomes pairing as bivalents would give diploid segregation ratios.

When the hair groups were present their development ranged from extremely slight to abundant. The presence or absence of groups 56 and 60 is apparently determined by a small number of major genes, but if present, their development is determined by more genes, probably by polygenes or modifying factors. All of the parent varieties are very heterozygous so that each hair group gene operates on a different genetical background in different individuals. Many genes in this background may influence the expression of the major hair group genes. Because of this the development of each hair group may differ in different individuals. When highly inbred lines of sugarcane are produced it may be possible to study the segregation of major hair group and other genes on uniform genetical backgrounds, and simpler segregations should occur. A major inbreeding programme is being carried out in Barbados (Stevenson[9]) and minor programmes are being carried out by the Queensland Bureau of Sugar Experiment Stations and by other organizations. Apart from possible value in practical breeding, inbred lines produced by this work may ultimately prove of great value in giving a greater insight into the genetical structure of sugarcane.

The genes determining hair group 56 appear to be completely independent of those determining groups 57 and 60. There is an association between the genes determining groups 57 and 60. An association of this kind may be due to genetical linkage or both groups may be influenced by the same gene or group of genes. Probably the association between groups 57 and 60 is not due to genetical linkage. The ratios differ from independent assortment not so much by an excess of parental combinations and a deficiency of non-parental combinations (typical linkage) as by the fact that group 60 does not occur unless group 57 is present. In the cross Co.419 / Co.301 a similar relationship seems to occur between group 60 and group 67. Group 67, a group of hairs on the blade of the leaf, is absent from Co.419 and present but extremely slight in Co.301, often occurring as only three or four long hairs near the base of the midrib on the upper surface of the leaf blade. When Co.419 and Co.301 were crossed some of the resulting individuals showed moderate development of group 67. However, group 67 did not occur in these individuals unless group 60 was present and group 60 did not occur unless group 57 was present. It seems possible that groups 57, 60 and 67 are associated in this cross, the genes determining group 60 exerting their effects only if genes determining group 57 are present, and the genes determining group 67 exerting their effects only if genes determining groups 57 and 60 are also present. This may be represented diagrammatically as follows :—

$$\xrightarrow{\quad L \quad}\text{Group 57}\xrightarrow{\quad M \quad}\text{Group 60}\xrightarrow{\quad N \quad}\text{Group 67,}$$

where L, M and N are genes operating at successive stages in development of the leaf. The failure of group 60 to appear in the absence of group 57 is in agreement with Artschwager's[1] observation that group 60 often occurs with group 57 but is found in fewer varieties, and indicates that it may be a general phenomenon in sugarcane.

The hair groups are regarded as qualitative characters. They are not greatly influenced by the environment and individuals fall into fairly well defined classes. Many characters of economic importance, especially yield, show continuous phenotypic variation (Stevenson[9]). Such quantitative characters may be determined by several genes each with individually small effects which are further masked by variations in the environment. For characters such as yield, individuals do not fall into clearly defined classes and the classical methods of genetical analysis cannot be used. During the last twenty years mathematical methods have been evolved for studying quantitative characters (Mather[7]). The comparison of clonal variation with the variation of seedling populations (Stevenson[8]) has a place in this work. The determination of the relative importance of heredity and environment in the expression of economic characters in sugarcane, and the calculation of the number of effective genetical factors determining these characters is of direct importance in improving our breeding and selection methods.

At present quantitative inheritance studies seem to offer more immediate advantages than qualitative studies. However, the two methods should progress together. Both fields are virtually unexplored. Considering the economic importance of sugarcane and the money spent on its improvement, these fields should be thoroughly explored in the future.

SUMMARY

The inheritance of Jeswiet's hair group numbers 56, 57 and 60 was studied in selfs and crosses of heterozygous sugarcane varieties. There was a strong indication that the presence or absence of hair groups 56 and 60 was determined by a small number of major genes. The results were in agreement with the hypotheses that the segregation of presence versus absence of group 56 was determined by one or two major genes in different crosses, that the segregation

of presence versus absence of group 60 was determined by one, two or three major genes in different crosses, that the genes determining the two groups were completely independent in inheritance and that the genes gave simple diploid segregations. There was no clear indication that group 57 was determined by major genes, nor was this possibility excluded. The quantitative development of the hair groups was probably determined by polygenes or modifying factors. The genes determining groups 57 and 56 were independent in inheritance but there was a definite association between hair groups 57, 60 and 67. This association was probably caused not by genetical linkage but by common genes operating at successive stages in development of the leaf.

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Dr. T. S. Raghavan presented the following two papers.

Paper

SUGARCANE AS A MATERIAL FOR GENETICAL STUDIES

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INTRODUCTION

Sugarcane breeding commenced towards the close of the last century with the discovery made independently in Java and Barbados of the capacity of the sugarcane flowers to set viable seeds. Then onwards within a short period of about sixty years, the hybrid canes had a sway over the indigenous canes grown in the diverse parts of this country and the other sugarcane growing countries of the world. It can well be added that the original sugarcane varieties are only grown here and there, their cultivation declining so rapidly that it is feared that soon they may become extinct.

One remarkable feature about sugarcane breeding is that even today after nearly about 60 years of practice, it still remains to a large extent a hit or miss affair. Hence the methods followed in sugarcane breeding are based on its cytogenetical features. It is nonetheless true that the more the cytogenetical features of sugarcane are unearthed, the greater appear the uncertainties connected with its breeding behaviour. The origin of these uncertainties is traceable to many factors—polyploidy, heterozygosity, cytoplasmic inheritance and parthenogenesis preceded by chromosome elimination *en bloc* or not, differential functioning of the gametes in fertilisation, absence of and sometimes capricious expression of the dosage effect of genes—these have been dealt with in a series of published papers (Raghavan, 1951 a, b, c ; 1952 a, b and 1954 : Parthasarathy, 1946, 1948 and 1951).

GENETICAL CONSTITUTION AND CYTOGENETICAL FEATURES

The fundamental fact about sugarcane is that as a breeding material, it is different from other crop plants. This of course is due to its genetical constitution which in its turn is dependent upon its evolution. The noble cane for example is a highly heterozygous polyploid with $2n=80$ chromosomes with a basic number of $x=10$. It could be described as an allo-octoploid. Because of this feature, there is a wide range of variations among the selfed progeny in such of those species as in which there are survivals. This is due to its high polyploid nature ; two or more fundamental forms have presumably entered into hybridisation in nature accompanied by chromosome duplication at different levels of its evolution. The various crosses and back-crosses that took place during their evolution have made them highly heterozygous for several pairs of genes. The prolonged vegetative propagation and somatic mutations might have increased the heterozygosity. Futher there is a large reserve of lethal genes as in *officinarum* which operates against the survival of the selfed progeny.

While polyploidy entails considerable disadvantages, it confers one advantage viz., autosyndesis and the consequent viability of the seedlings of even distant crosses, provided the parental chromosomes are compatible enough to co-exist to make up the hybrid complement. Thus interspecific and intergeneric crosses are possible more commonly than in any other plant. Synapsis seldom takes place between the chromosomes of the opposite parents. It is almost always among the chromosomes of either parent only i. e. autosyndetic. Coupled with this the heterozygosity of the chromosomal material from both the parents renders infinite odds against anticipating any desired combinations. Repetition of well known crosses have so far failed to give a variety identical with the original. For instance parental crosses for Co. 419 (P.O.J. 2878 x Co. 290) and Co. 421

(P.O.J. 2878 x Co. 285) have been repeatedly made for about four years. Though several thousand seedlings were raised and studied, there is not yet found an exact replica of either Co. 419 or Co. 421.

Another peculiarity which is almost unique in sugarcane hybridisation is that no prediction can be made as to what the chromosome number in a particular cross would be like. Normally when two plants are crossed the offspring which results will have the "2n" number which will be the sum of the haploid numbers of the parents concerned. *Saccharum* differs from other crops in this respect that it contributes on the egg side n, 2n and unexpected number of chromosomes, for instance, if an *officinarum* ($n=40$) is crossed with a *Spontaneum* ($n=32$), the hybrid that results would show $2n=112$ being the product of $2n+n$. In some intergeneric crosses, as for example with *Narenga* or *Sclerostachya*, *Saccharum* has been found to contribute 68 chromosomes which is neither its haploid nor its diploid number. Zw. Cheribon with Co. 285, has contributed 68 chromosomes instead of either 40 (n) or 80 (2n) to form Co. 453 (Raghavan 1951 a, 1952 a, b).

Reciprocal differences have indicated the presence of cytoplasmic inheritance in many forms which fact has been corroborated by the recorded occurrence of male sterility as a maternally inherited character in crosses involving *S. spontaneum* as the pistil parent (Raghavan, 1951 c).

Apart from the problem of heterozygosity and lethality, there is the complication of parthenogenesis also. Many of the noble canes are self sterile, and in some the anthers do not dehisce at all. Even these in which there is pollen shedding there are practically no survivals in the selfed population. The few that do survive are products of diploid parthenogenesis. It is now known that many of the economic crosses are parthenogenetically derived (Raghavan 1954 a, and 1954 b) and as such this phenomenon appears to play a very important role in sugarcane breeding. The formation of the diploid egg is not through a suppression of meiosis, but is a post-meiotic phenomenon and as such equivalent to fertilisation. Hence seedlings derived from such parthenogenesis show wide variations that are characteristic of seedlings arising out of hybridisation of polyploid complexes like sugarcane. Nor is it all : instead of diploid eggs, egg gametes with unexpected chromosome numbers also develop into parthenogenetic seedlings showing unexpected chromosome numbers. Due to these complications, there is very little that could be done for purification of sugarcane. Thus inbreeding and pure line selections are of little avail in sugarcane breeding.

In some crosses an apparent dosage effect of the genes is seen. This is especially so in the nobilization and spontanisation back-crosses. In some instances, the dosage effect of the chromosomes is to some extent masked by the interaction of the maternal cytoplasm with the genes. This is well seen in the first generation hybrids between *S. officinarum* x. *S. Spontaneum* and their reciprocal crosses. There are yet a few instances in which the dosage effect of *officinarum* genes does not appear to affect phenotypic expression. For instance P′ 899/3 is a product of 2nd nobilization involving Co. 453 as the mother having come into being through n+n. The number of *officinarum* chromosomes in this is 94 in a total complement of 102. In its reciprocal cross (which is comparable to P.O.J. 2725) the chromosome constitution is quite different being a product of 2n+n. As such the number of *S. officinarum* chromosomes in this seedling (P′ 890/1) is very high *i.e.*, 134 in a total complement of 142. In spite of this, however, the seedlings of the crosses are almost identical reciprocally in their gross external features indicating an apparent ineffectiveness of the increased dosage of *officinarum* genes.

Another peculiar phenomenon recently observed in the hybrids of *Saccharum* is the elimination of chromosomes during mitosis in the somatic tissue. In a seedling P′ 878/1 (Zw. Cheribon × Co. 285) during mitotic division in the root tip cells, elimination of a small number of chromosomes as a group after the formation of an accessory spindle has been noted. Such elimination of chromosomes in group or groups can give rise to plants having widely deviating chromosome numbers. This, in a way, can be considered as a process quite the reversal of polyploidy and it is rather paradoxical that on one side there is the formation and functioning of unreduced gametes and on the other, there is the reduction of chromosomes through elimination of chromosomes *en bloc*.

These are some of the difficulties confronting the sugarcane breeder ; the vagaries of sugarcane which are the necessary consequences of its genetical constitution and evolution, render it a difficult material for genetical studies. Some data gathered in representative intra-specific, inter-specific and inter-generic crosses are presented and wherever possible statistically analysed.

CROSSES STUDIED

A. Intra-specific :

S. officinarum x. *S. officinarum* :—(a) Creole x Purple Mauritius, (b) Purple Mauritius x Creole, and (c) their F_2 as well as their back-crosses.

B. Inter-specific :

S. officinarum x *S. Barberi* :—(a) K. Boothan x Saretha, (b) Saretha x K. Boothan, (c) K. Boothan x Katha, and (d) Katha x K. Boothan.

C. Inter-generic :

S. Spontaneum x *Sclerostachya* and its F_2 and back-crosses.

D. Miscellaneous crosses :

Co. 605 x P. 8331 and its reciprocal cross.

Co. 678 x P. 8331 and its reciprocal cross.

Characters like rind colour, shape of the bud, ivory markings on the rind, tillering, ligule, ligular process, leaf sheath, leaf length and width (lamina), height and thickness of the culms were studied.

A. Intra-specific cross.

S. officinarum var. Creole x *S. officinarum* var. Purple Mauritius.

Creole is a medium thick cane (about 2.6 cms. diameter) having green stem with a very light yellow tinge. It is erect in habit and grows to a height of approximately 4 ft.The leaves which are not as broad as those of Purple Mauritius stand out erect without drooping. The drying leaves clasp the stem loosely but do not self strip as in the case of Purple Mauritius. Purple Mauritius is a thick cane (3.8 cms. in diameter) having a deep purple rind colour (and hence the name). It is erect in habit and grows upto approximately 5 ft. in height. Its foliage is erect but the tip of the leaves droop. It is practically self stripping.

Stem colour : To study the inheritance of rind colour, Creole as pistillate parent, was crossed with Purple Mauritius and six F_1 seedlings were obtained. Four of the seedlings were deep purple, one light purple and one green. The reciprocal cross yielded nine seedlings of which seven are deep purple, one light purple and one green. The purple rinded seedling No. 2 of Purple Mauritius x Creole, was selfed and thirty F_2 seedlings were obtained. The rind colour of these seedlings are as follows—7 purple, 11 light purple, 3 green with purple tinge and 9 green. The same seedling was back-crossed with purple Mauritius and it yielded 78 seedlings of which 31 were purple, 27 light purple, 1 light purple with green tinge, 2 green with purple tinge, 1 green with traces of purple and 16 green. Table I and Table II summarize the results obtained in these crosses. The majority of the F_1 seedlings have either dark purple or light purple rind but there is one individual in the cross eitherway that had green rind colour like Creole. It is also worthy of note that no colour which can be regarded as intermediate was observed.

TABLE I

INHERITANCE OF RIND COLOUR IN CREOLE (GREEN) × PURPLE MAURITIUS (PURPLE) AND ITS RECIPROCAL CROSS

	Purple	Light purple	Light purple with green tinge	Green with purple tinge	Green with trace of purple	Green
F_1	4	1	—	—	—	1
Reciprocal cross	7	1	—	—	—	1
F_2	7	11	—	3	—	9
Back-crosses	31	27	1	2	1	16

TABLE II

GOODNESS OF FIT OF RATIOS IN F_2 AND BACK-CROSS PROGENIES

Values	F_2 progeny					Back-cross progeny			
	3 : 1 ratio		1 : 2 : 1 ratio			1 : 0 ratio		1 : 1 ratio	
	Purple	Green	Purple	Intermediate	Green	Purple	Green	Purple	Green
Observed	21	9	7	14	9	62	16	62	16
Expected	22.5	7.5	7.5	15	7.5	78	0	39	39
x^2	0·130		0·4			—		13·5	
Probability	0.70—0.80		0.80—0.90				0.0	.001	

In the F_2 progeny, the ratios 3:1 and 1:2:1 are good fits, the latter being slightly better as indicated by the probability values. However, these inheritance ratios are not in keeping with the phenotypic expression of the F_1 plants, since a 3:1 ratio would require purple colour and 1:2:1 ratio an intermediate colour in all the F_1 seedlings.

For the back cross progeny, the observed values do not fit into either of the expected ratios.

Hence the inheritance of rind colour does not appear to follow normal Mendelian segregation.

B. Inter-specific crosses.

2. *S. officinarum* x *S. Barberi* :—

K. Boothan x Saretha and its reciprocal.
K. Boothan x Katha and its reciprocal.

In these crosses only the F_1 seedlings were available eitherway and these were analysed to see the reciprocal differences if any, as regards particular traits.

In the first cross *S. officinarum* var. K. Boothan has been used as the pistil parent and var. Saretha as the staminate parent. Seventy five seedlings were obtained as the F_1 of the direct cross and in its reciprocal only 25. Characters such as the number of tillers, bud shape, ligule, ligular process, leaf sheath, ivory markings on the culm, height, thickness, leaf length and leaf width have been studied. The analyses of the results are presented in Tables III to VII. It will be seen from the summary of these that the reciprocal differences are significant in most of the cases.

INHERITANCE OF CHARACTERS IN RECIPROCAL MATINGS OF *S. OFFICINARUM* × *S. BARBERI*

TABLE III

TILLERS

	Tiller numbers						
	3-6	7-10	11-14	15-18	19 & above	Total	Mean
K.Boothan × Saretha	16	36	17	4	2	75	7.4
Saretha × K. Boothan	—	4	5	4	12	25	17.3
Total	16	40	22	8	14	100	

$X^2=32.82$ Highly significant.

	Below 4	4-7	8-11	12 & above	Total	Mean
K. Boothan × Katha	3	10	6	2	21	6.8
Katha × K. Boothan	6	8	1	3	18	5.7
Total	9	18	7	5	39	

$X^2=2.69$ not significant.

TABLE IV

HEIGHT

	4′	5′	6′	7′	8′	9′	10′	Total	Mean
K. Boothan × Saretha	2	3	8	26	17	13	6	75	7′-9″
Saretha × K. Boothan	5	5	12	3	—	—	—	25	5′-7″
Total	7	2	20	29	17	13	6	100	

Mean height for the two populations is significantly different.

	Below 4′	4′	5′	6′	7′	8′	Total	Mean
K. Boothan × Katha	2	—	3	3	4	8	20	7·1
Katha × K. Boothan	15	2	—	1	—	—	18	3.8
Total	17	2	3	4	4	8		

Mean height for the two populations is significantly different.

TABLE V

THICKNESS

	.25″-.45″	.46″-.65″	.66″-.85″	.86″-1.05″	1.06″-1.25″	1.26″-1.45″	1.46″-1.65″	Mean
K. Boothan × Saretha	—	2	13	25	24	10	1	1.03
Saretha × K. Boothan	14	11	—	—	—	—	—	0.44
Total	14	13	13	25	24	10	1	

The crosses differ significantly in their mean thickness.

	Below 0.4″	0.4″	0.6″	0.8″	1.0″	1.2″	Total	Mean
K. Boothan × Katha	—	1	4	11	4	1	21	0.35″
Katha × K. Boothan	2	8	6	1	—	1	18	0.58″
Total	2	9	10	12	4	2	39	

The crosses differ significantly in their mean thickness.

TABLE VI

LEAF LENGTH

	23.5″ 29.5″	29.6″ 35.5″	35.6″ 41.5″	41.6″ 47.5″	47.6″ 53.5″	53.6″ 59.5″	59.6″ 65.5″	Mean	Standard deviation
K. Boothan × Saretha	1	5	13	18	22	13	3	46.1″	7.72″
Saretha × K. Boothan	7	7	6	4	1	—	—	34.4″	6.40″
Total	8	12	19	22	23	13	3		

	20″	25″	30″	35″	40″	45″	50″	55″	Mean
K. Boothan × Katha	—	1	—	3	3	4	7	2	47.3″
Katha × K. Boothan	8	8	2	—	—	—	—	—	24.8″
Total	8	9	2	3	3	4	7	2	

The crosses differ significantly in their mean leaf length.

TABLE VII
LEAF WIDTH

	0.3″	0.6″	0.9″	1.2″	1.5″	1.8″	2.1″	2.4″	Total	Mean
K. Boothan × Saretha	—	—	1	12	30	22	9	1	75	1.73″
Saretha × K. Boothan	17	6	2	—	—	—	—	—	25	0.54″
Total	17	6	3	12	30	22	9	1	100	

The crosses differ significantly in their mean leaf width.

	Below 0.6″	0.6″	0.8″	1.0″	1.2″	1.4″	1.6″& above	Total	Mean
K. Boothan × Katha .	—	—	—	3	1	9	8	21	1.5
Katha × K. Boothan	9	6	3	—	—	—	—	18	0.57
Total	9	6	3	3	1	9	8	39	

The crosses differ significantly in their mean leaf width.

C. Inter-generic cross.

S. spontaneum x *Sclerostachya* and its F_2 and back-crosses.

A large population of seedlings consisting of the F_1, F_2 and backcrosses were available, in an intergeneric cross between *S. spontaneum* Coimbatore *Sclerostachya*. The *S. Spontaneum* used as the pistil parent in this cross is a local form with $2n=64$ chromosomes. It is a perennial wild grass, often forming well defined tufts, varying in height from 5-7 feet with thin round or oval stem, putting forth lanceolate panicles with profuse fertile pollen. This is mostly used for infusing vigour in the progeny.

The male parent used is a wild 'Terai' grass having $2n=30$ chromosomes. The culms are vigorous, tall, reedlike, attaining a height of 6′, stem round, fistular, underground runners present, with root eyes absent. The inflorescence is short, linear, oblong panicle, copper-coloured and having profuse fertile pollen. This is increasingly used now for vigour, early flowering and disease resistance.

SUMMARY OF THE RESULTS

Character	*S. officinarum* x Saretha and Reciprocal	*S. officinarum* x Katha and Reciprocal
Tillers	Highly significant	Not significant
Height	Significantly different	Significantly different
Thickness	Differ significantly	Differ significantly
Leaf length	Significantly diffferent	Differ significantly
Leaf width	Differ significantly	Differ significantly
Bud shape	Significant	Not significant
Ligule	Not significant	Significantly different
Ligular process	Highly significant	No significant difference
Ivory markings	Not significant	Not significant

TABLE VIII

DISCRIMINATING CHARACTERS OF *S. SPONTANEUM* COIMABTORE AND *SCLEROSTACHYA*

Character	*S. Spontaneum* Coimbatore ♀	*Sclerostachya*
Tillering	13	50
Height of the stalk	79″	60″
Leaf length	38″	33″
Leaf width	0.3 cms.	1.0 cms.
Brix in juice	8.0%	3.0%

Twenty one hybrids were obtained. The chromosome number of the hybrids ($2n=79$) revealed the functioning of diploid egg. The Tables IX to XIII show the inheritance as regards tillers, height, leaf length and width and brix.

So far as tillers are concerned, the means of the parent types differ by 37 tillers. The maximum of tillers in the hybrid is only 24, and this was exhibited by only one seedling. The mean for F_2 is 14.9 which is close to that of F_1. The coefficient of variation of the F_2 is as much as 50.8. Some plants are found in this generation with tillers as many as the mean of *Sclerostachya*, and some with tillers as few as that of *S. spontaneum*, with others ranging in between. But the number of individuals having few number of tillers (as that of the pistil parent *S. spontaneum*) is more than the ones, resembling the opposite parent. These facts may best be interpreted by assuming that these two probably differ by a series of factors for tillering, that these lack dominance and that their segregation in F_2 is responsible for the increased variability which this generation shows. This assumption will hold good only in cases where the chromosomes are known to pair allosyndetically. The autosyndetic pairing of the chromosomes in *Saccharum* and allied genera precludes this possibility. The seeming behaviour of the trait, in accordance with theory of multiple factor hypothesis, may be purely a chance, or it may be that some of the chromosomes have paired allosyndetically to give this segregation. Seedling No. 3 of the F_1 was back-crossed with *Sclerostachya*, and 29 seedlings were obtained. One interesting feature about the behaviour of these back-crosses, is that inspite of the back-crossing with the parent (*Sclerostachya*) seedlings having more traits of *Sclerostachya* were not recovered.

As regards height, even though the behaviour is similar to that of tillers, the variants of F_1/F_2 is significant and the variance of the backcross is not significantly different from the variance of F_1, which is contrary to the multiple factor hypothesis. The same is the case with the leaf length and width, and brix also. One peculiar feature observed in the case of brix is that though the parents concerned have 8 (*S. spontaneum*) and 3 (*Sclerostachya*), some of the F_1 hybrids have brix to the extent of 12-14, and still more 20-22 in some of the F_2 population. This may be due to either cumulative effect of genes, or due to some peculiar combination of genes unknown. The variance or F_1 as regards brix is not significantly different

TABLE IX

FREQUENCY DISTRIBUTION OF THE NUMBER OF TILLERS WITH THE MEAN, STANDARD DEVIATION AND COEFFICIENT OF VARIATION

	0-4	4-8	8-12	12-16	16-20	20-24	24-28	28-32	32-36	36-40	40-44	44-48	Total	Mean	Standard deviation	Coefficient of variation
P_1 (*S. Spontaneum*)														13		
P_2 (*Sclerostachya*)														50		
F_1	—	0.5	2.5	6	7.5	3.5	1	—	—	—	—	—	21	16.7± .9	4.2	25.1
F_2	—	10.5	37.5	26.5	16.5	7	5	3.5	5	1	5	1.5	111	14.9± .72	7.57	50.8
Back-cross with *Sclerostachya*	0.5	1.5	7.5	8	5.5	3	2	1	—	—	—	—	29	15.2±1.1	5.9	30.8

Note : For those seedlings where the number of tillers come on the border line, half of them are put in each class.

Remarks : The variances of F_2 and back-cross are significantly different from those of F_1 ($F_2 > F_1$). This is the only character in which the result seems to conform with the theory of polygenic inheritance (but the distribution is not symmetrical).

$$n \text{ (The number of independent effective factors)} = \frac{D^2}{8(V_{F_2} - V_{F_1})}$$

By this formula " *n* " works out to be between 4 and 5.

If with these values of *n*, we try to find out the expected frequencies, the fit will be extremely poor, as the majority of the values are nearer the parent having smaller number of tillerings. Also quite an appreciable number of observations are below the parental value.

TABLE X

FREQUENCY DISTRIBUTION OF THE HEIGHT OF CANE WITH MEAN, STANDARD DEVIATION AND COEFFICIENT OF VARIATION

	31.5- 37.5	37.5- 43.5	43.5- 49.5	49.5- 55.5	55.5- 61.5	61.5- 67.5	67.5- 73.5	73.5- 79.5	79.5- 85.5	85.5- 91.5	91.5- 97.5	Total	Mean	Standard deviation	Coefficient of variation
P_1 (*S. Spontaneum*)									1				79		
P_2 (*Sclerostachya*)						1							60		
F_1					1	3	1	8	1	4	3	21	79 ± 2.4	10.8	13.6
F_2	3	6	19	32	31	18	6	1	—	—	—	116	$55.2 \pm .76$	8.16	14.7
Back-cross ($F_1 \times$ *Sclerostachya*	2	2	1	2	9	10	2	—	—	1	—	29	58.6 ± 2.08	11.2	19.1

Remarks :

$$\frac{\text{Variance } F_1}{\text{Variance } F_2} = 1.7 \text{ significant } (F_2 < F_1)$$

Variance of back-cross is not significantly different from variance of F_1.

The observation is in contradiction to the Multiple factor hypothesis theory.

TABLE XI

FREQUENCY DISTRIBUTION OF LEAF WIDTH (IN INCHES) WITH MEAN, STANDARD DEVIATION AND COEFFICIENT OF VARIATION

	.3 or below	.4	.5	.6	.7	.8	.9	1.0	1.1	1.2	1.3	1.4	Total	Mean	Standard deviation	Coefficient of variation
P_1 (*S. Spontaneum*)	1													0.3		
P_2 (*Sclerostachya*)								1						1.0		
F_1	2	—	1	2	2	3	2	4	1	3	—	1	21	0.85±.068	0.313	36.8
F_2	5	12	25	45	14	9	3	—	1	1	—	1	116	0.59±.016	0.17	28.8
Back-cross with *Sclerostachya*	2	3	8	8	5	3	—	—	—	—	—	—	29	0.57±.025	0.17	29.9

Remarks :

$F\ (20.115) = \frac{\text{Variance of } F_1}{\text{Variance of } F_2} = 3.35$ highly significant.

F_1 is more inclined towards the parent with smaller leaf width.

The inheritance is not in accordance with the Mendelian Law. The approximate formula for finding the effective number of genes $n = \frac{D^2}{8(V_{F_2} - V_{F_1})}$ gives negative values of *n*.

TABLE XII

FREQUENCY DISTRIBUTION OF BRIX IN JUICE OF CANES WITH MEAN, STANDARD DEVIATION AND COEFFICIENT OF VARIATION

	4.5-6.5	6.5-8.5	8.5-10.5	10.5-12.5	12.5-14.5	14.5-16.5	16.5-18.5	18.5-20.5	20.5-22.5	Total	Mean	Standard deviation	Coefficient of variation
P_1 (*S. Spontaneum*)											8.0		
P_2 (*Selerostachya*)											3.0		
F_1	6	4	5	4	2	—	—	—	—	21	8.6 ± 0.6	2.8	32.5
F_2	1	9	18	20	21	18	13	11	5	116	13.6 ± 0.34	3.66	26.9
Back-cross with *Sclerostachya*	—	3	4	15	3	—	2	1	—	28	11.8 ± 0.51	2.7	22.8

Remarks : The variance of F_1 is not significantly different from that of F_2 and back-cross. This is again in contradiction with the theory.

TABLE XIII

FREQUENCY DISTRIBUTION OF THE LEAF LENGTH (IN INCHES) WITH MEAN, STANDARD DEVIATION AND COEFFICIENT OF VARIATION

	26.5- 30.5	30.5- 34.5	34.5- 38.5	38.5- 42.4	42.5- 46.5	46.5- 50.5	50.5- 54.5	54.5- 58.5	58.5- 62.5	62.5- 66.5	66.5- 70.5	70.5- 74.5	Total	Mean	Standard deviation	Coefficient of variation
P_1 (*S. Spontaneum*)			1											38		
P_2 (*Sclerostachya*)		1												33		
F_1	—	—	1	—	—	1	7	3	4	2	2	1	21	57.2±1.7	7.9	15.4
F_2	1	7	25	35	25	18	5	—	—	—	—	—	116	41.8±0.47	5.04	12.0
Back-cross with *Sclerostachya*	3	—	11	4	8	3	—	—	—	—	—	—	29	39.6±1.05	5.6	14.1

Remarks : Variance of F_1 is significantly greater than the variance of F_2.

Variance of F_2 does not differ significantly from the variance of back-cross.

Variance of F_1 is significantly greater than the variance of back-cross.

According to the multiple factor hypothesis the variance of F_1 should be less than both F_2 and back-cross.

The observed result is in contradiction with the theory.

TABLE XIV
DATA ON HIGH YIELD AND SUCROSE COMBINATIONS
(In reciprocal crosses)

Cross	Number of seedlings		Brix %								Weight per Cane in lbs.							
	Total	Examined	Maximum	Minimum	15—16	17—18	19—20	21—22	23—24	Remarks (Statistical)	Maximum	Minimum	Below 1 lb	1·01-2·00	2·01-3·00	3·01-4·00	4·01-4.50	Remarks (Statistical)
Co.605 x P.8331	280	181	24.0	15.0	8	86	72	14	1	x^2 54.80 $\overset{(3)}{x^2_{0\cdot01}}$ 11.345 *Highly significant* There are more number of seedlings with greater Brix in the cross P.8331 x Co. 605 than in its reciprocal.	3.25	0.54	34	125	21	1	—	x^2 14.47 $\overset{(2)}{x^2_{0\cdot01}}$ 9.21 *Highly significant* There are more number of seedlings with higher weight per cane in the cross Co. 605 x P. 8331 than in its reciprocal.
P.8331 x Co.605	280	198	24.0	15.0	5	38	84	53	17		3.50	0.50	69	113	11	2	—	
Co.678 x P.8331	150	120	23.0	13.0	36	53	27	3	1	x^2 12.090 $\overset{(3)}{x^2_{0\cdot01}}$ 11.345 *Significant* There are more number of seedlings with higher Brix in the cross P.8331 x Co. 678 than in its reciprocal.	3.00	0.75	11	83	26	—	—	x^2 19.843 $\overset{(2)}{x^2_{0\cdot01}}$ 9.21 *Significant* There are more number of seedlings with higher weight per cane in the cross Co. 678 x P. 8331 than in its reciprocal.
P.8331 x Co.678	210	170	22.0	14.0	32	50	64	24	—		2.60	0.50	41	115	14	—	—	
Co.605					15.0												4.20	
Co.678								21.0							2.40			
P.8331								22.0						1.82				

from that of F_2 and backcrosses. This is again in contradiction with the multiple factor hypothesis.

D. Miscellaneous crosses.

Co. 605 x P. 8331.

P. 8331, a complicated hybrid, is now increasingly used as one of the parents for introducing richness to juice. Likewise Co. 605 gives seedlings with high yield. A combination of these two parents and their reciprocal crosses are expected to give a number of seedlings combining the richness of P. 8331 and the high yielding capacity of Co. 605.

A total of nearly 379 seedlings in the crosses either way were studied. P. 8331 as mother in the above cross has yielded a large number of seedlings with high brix ; as many as 80% of the total population appear to have inherited the maternal richness. Likewise Co. 605 as mother has yielded seedlings having high yield. This seems to support the existence of cytoplasmic inheritance.

CONCLUSIONS

The difficulties of handling sugarcane as a genetical material would be apparent from what has been said so far. Indeed Parthasarathy (1951 b) is of the opinion that sugarcane is not a suitable plant for genetical studies. That of course is the inevitable consequence of its being a complex polyploid hybrid. The vagaries exhibited in the crosses studied such as the clear-cut absence of dominance or recessive characters, the absence of uniform intermediate nature of the F_1 hybrids, and absence of segregation and failure to recover the parental types in the F_2 go to prove the statement made above. The only way of restoring a high degree of genetical purity appears to be to get at some lower diploid forms which may be the progenitors of sugarcane. Back-crossing with forms which are likely to have played a role in the origin of sugarcane while bringing about the desired result, introduces at the same time a very complicated problem of how to eliminate the chromosomes other than those of sugarcane.

So far as the evolution of economically better varieties of sugarcane is concerned, it is bound to involve a very large element of chance which cannot be eliminated altogether. Hybridisation, selection and testing are the most important features in the evolution of economic types. As Stevenson (1943) points out " it includes a study of the fundamental causes of variability in seedling populations, the differential response shown by varieties under distinct environments, and the way in which adaptation to particular localities may be understood from a knowledge of individual growth types ". From a study of such features, as the time and extent of tiller formation, cane growth rate and the arrowing, it may be possible to forecast the type of conditions to which a seedling will be most suitable. Each seedling may be expected to give of its best under a particular set of environmental conditions. It looks as if maximisation of production can be achieved only by breeding newer varieties for different tracts each adapted to a comparatively narrow range of environmental conditions. Hence the importance of testing each new promising variety in different types of environments cannot be overemphasised. From this point of view the term 'sugarcane breeding' need not be restricted to the narrow sense of hybridisation alone but it comprehends individual varietal response to differential environments.

SUMMARY

The inter-relationship between genetics and plant breeding has been emphasised. From the realm of art, plant breeding has passed on to the realm of an exact science with the re-discovery of laws of Mendelian heredity at the turn of the century. In the earlier investigations into the field of heredity, data were gathered by methods considered purely genetical. With the discovery of the presence of the genes, the hereditary units, genetics has come to assume a new complexion. Correlation of data obtained by genetical procedure with observations made by cytological technique, has become the rule in present day practice. This dual approach—'cyto-genetics'—involves a sound knowledge of statistical methods.

The methods followed in sugarcane breeding are of necessity a consequence of its cyto-genetical features. The fundamental fact to remember about sugarcane in this connection is that as a breeding material, it is different from the other crop plants. This, of course, is due to its genetical constitution which in its turn is dependent upon its evolution. It is a highly heterozygous polyploid complex with a large reserve of lethal genes which especially in the *officinarums* are responsible for there being practically no survivals in the selfed progeny. It is the clonal propagation that has made it survive the competition. The presence of diploid parthenogenesis in most of the pollen sterile forms adds to the complexity. There is therefore very little that could be done for " purifying " sugarcane. Thus inbreeding and pureline selection are of little avail in sugarcane breeding. The vagaries exhibited by sugarcane as a breeding material and their cytological basis have been briefly described. Phenomena such as elimination of chromosomes *en bloc*, semblance of dosage effect of genes in some crosses and its absence in others, irregular phenotypic expression not easily explicable by established cytological causes, the presence of some sort of cytoplasmic inheritance in some crosses, non-segregation of parental characters due to autosyndetic pairing of the chromosomes—these have been indicated. For genetical studies sugarcane is not a favourable material.

The data that have been gathered are presented in a statistically analysed form. In some crosses, the reciprocal differences with reference to particular characters, have been found to be statistically significant indicating the presence of an inheritance which is based upon an inter-action of the genes with the maternal cytoplasm. This has been found to apply even in cases where economic characters like yield and sucrose have been taken into consideration.

Some of the characters like tiller number, height, leaf length and width, appear

prima facie polymeric in their inheritance. But on subjecting the collected data to statistical analysis, it was found that they did not conform to the expectation.

Similarly when single qualitative characters are taken for genetical analysis, it was found that they did not conform to either monogenic or digenic inheritance. This is according to highly impure material, and the chances of establishing homozygosity are practically nil, owing to inherent cyto-genetical complications.

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Paper

THE PHYLOGENY OF SACCHARUM AND RELATED GENERA

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INTRODUCTION

The study of the origin of cultivated canes, is of immense value to the plant breeder, in the task of evolving new varieties suited to the varied environmental conditions. While many agronomical characters as those connected with yield and quality, are seen in cultivated plants, those constituting hardiness, resistance to diseases, drought and pests, are often met with in wild relatives. The importance of this aspect of breeding was first realised by Vavilov who explored regions that constituted the centres of origin of the more important crop plants and made a remarkable collection of the related wild forms. As a result of such a collection, potato breeding has been revolutionised making it possible to tackle the most important problems of synthesising fungus and virus resistant varieties. Muntzing (1951) successfully introduced the desirable genes of *Secale* into *Triticum* with the result that the "*Triticales*" are capable of growing in sandy soils where no wheat can grow and yet yield as high as 90% of the best wheats ; in addition, they have good baking quality, high protein content, early maturity and winter hardiness.

Being the bearers of heredity characters the chromosomes have a direct bearing on evolutionary processes, and as such are invaluable guides, in tracing out phylogeny. The number and morphology of chromosomes and other karyological features (Babcock, Stebbins and Jenkins, 1942), the number of nucleoli and satellites (Gates, 1937), together with the pairing behaviour (Sax, 1935), and secondary association (Lawrence, 1931 ; Gatschecide, 1937 ; Nandi, 1936 ; Raghavan et al, 1939, 1947) have been useful pointers to interspecific and intergeneric relationship. In the evaluation of taxonomic relationship, the degree of chromosomal pairing is often an unmistakable measure of the degree of affinity between the concerned species. In species with the same chromosome number, the greater the number of bivalents, the greater the fertility, and the closer the relationship, as has been found for example by Clausen (1931) in Viola, e.g., *V. tricolor* $(n=13)$ x *V. alpestris* $(n=13)=13_{ii}$. The pairing behaviour in plants with different chromosome numbers has been classified by Tackholm (1922) into three main types. They are firstly Drosera Scheme of pairing, where the affinity between the chromosomes of the two parents is greatest, and where the chromosomes of the parent with the lesser number pair with their homologues in the other parent, the rest remaining in an unpaired condition, e.g., *Triticum* (Sax, 1928), *Nicotiana tabacum* $(n=24)$ x *N. sylvestris* $(n=12)=12_{ii}+12_{i}$

(Goodspeed and Clausen, 1927), *Brassica Juncea* ($n=18$) x *B. campestris* ($n=10$) $=10_{ii}+8_{i}$ (Ramanujam and Sreenivasachar, 1943). Secondly in the *Hieracium Boreale* type, there is only weak affinity, e.g., *Nicotiana tabacum* ($n=24$) x *N. glutinosa* ($n=12$) (0 to 8_{ii}, Raghavan and Srinivasan, 1941). Finally in the *Pygrarea* type there is little or no affinity e.g., *Nicotiana* (Goodspeed, 1934), *Crepis* (Collins and Mann, 1923).

Cytogenetical studies and the pairing behaviour between the genomes of the parents concerned have now established the origin of many cultivated plants through hybridisation and chromosome duplication. The wheats may be taken as an example. Species of wheat fall into three groups, diploid *einkorn* wheats ($2n=14$), tetraploid *emmer* or hard wheats ($2n=28$) and hexaploid *vulgare* or soft wheats ($2n=42$). The work of Sax, Kihara and others showed that the chromosome complement of *emmer* wheats contains a set of 7 chromosomes similar to those of *einkorn* wheat and a set of 7 other chromosomes derived from another plant. *Vulgare* wheats contain 14 pairs of chromosomes similar to the *emmers* and 7 pairs similar to those found in the genus *Aegilops*. Thus the *emmer* wheats must have arisen as allotetraploid hybrids. The *vulgare* wheats are allohexaploid hybrids derived from *emmer* like and *Aegilops* like ancestors. It is now known that the *emmers* are allotetraploid having 7 pairs of chromosomes from *T. monococcum* (AA) and 7 pairs from *Agropyron triticeum* (BB). The bread wheats (*T. aestivum*) belonging to the *vulgare* group, are allohexaploids (AABBDD) with three groups of 7 pairs each, of which AA and BB are contributed by the *emmer* wheat (*T. monococcum* and *Agropyron triticeum*) and DD from *Aegilops squarrosa*.

The American cottons *Gossypium barbadense* and *G. hirsutum* having 26 pairs of chromosomes ($2n=52$) are now known to be amphidiploid derivatives from crosses between two species having $2n=26$. A group of diploid species ($2n=26$) occurs in a wild state in Central America and another group also having the same chromosome number occurs in the old world, tropical Asia, Africa etc. The New world tetraploid cottons contain 13 pairs similar to those found in American diploids and 13 pairs similar to those found in Asian diploids. The tetraploid species presumably arose through hybridisation between the American and Asiatic diploids and doubling of the chromosome complements. Similarly the cultivated *Brassica juncea* ($2n=36$) is an amphidiploid, having the genomes of *Brassica campestris* ($n=10$) and *B. nigra* ($n=8$) (Ramanujam and Srinivasachar, 1943). Goodspeed (1934) after a study of *Nicotiana* says "that there is no justification for a disbelief in the significance of pairing as indication of relationship ". Ramanujam (1937) is of the view that "while conjugation of chromosomes indicates a kind of homology between them, non-conjugation does not necessarily always mean non-homology " and as such counsels caution before arriving at any conclusion.

TAXONOMY AND DISTRIBUTION OF SACCHARUM AND RELATED GENERA

The genus *Saccharum* has a wide range of distribution, a proper understanding of which is essential before the various inter-relationships are studied. This genus ranges from the colder regions of the subtropics down to the tropical areas of Java, Sumatra, etc. *S. officinarum* flourishes well in the tropical belts of South India, Java and New Guinea. *S. Barberi* is confined to the subtropical belt of India, while *S. sinense* is a native of China. *S. robustum* is limited to the polynesian islands of New Guinea, New England and New Hebrides. *S. edule* is endemic to New Guinea and does not occur on the islands east of Hebrides. Only *S. spontaneum* is seen in all these areas, with its diversified habit, adapted to the different ecological conditions of the tropical and temperate regions, including the colder Himalayan slopes. Of the related genera, special mention may be made of *Sclerostachya*, *Narenga* and *Erianthus* whose taxonomic position is controversial. Till very recently these were included in the genus *Saccharum-Sclerostachya* under *Eu-Saccharum*, *Narenga* as *S. narenga* - while most of the species of *Erianthus* were regarded as species of *Saccharum*.

CHROMOSOME NUMBERS IN SACCHARUM AND RELATED GENERA

Compared to the basic number of 10, to which this tribe belongs, these species are all allopolyploids of a high order. *S. officinarum*, excepting variety Kajla ($2n=68$, Parthasarathy 1946), is an octoploid (Bremer 1925; Dutt and Subba Rao 1933; and Raghavan, unpublished). *S. spontaneum* has the widest range from $2n=40$ to $2n=128$ (Parthasarathy and Subba Rao 1946; Moriya 1950 ; Janaki Ammal 1936; Starret 1948). *S. Barberi* has four well defined chromosomal groups ranging from $2n=82$ to 124, while *S. sinense* shows $2n=118\text{-}122$ (Bremer 1925; Subramaniam 1946). *S. robustum* has chromosome numbers from $2n=60$ to 120 (Starret quoted from Artschwager 1948 ; Grassl 1946), while *S. edule* has $2n=70$ to 120 (Grassl 1946). A study of the few *robustum* clones available at this Institute reveals numbers different from those reported by Starret with $2n=64$, 72, 80, 84 and 96 (Sundararaghavan 1954). The genus *Erianthus* can be divided into 3 sub-groups, and the various species under them have the diploid numbers from 20 to 60 (Subba Rao and Raghavan, 1951). *E. maximus* is reported to have $2n=60\text{-}100$ (Grassl, 1946). The diploid number of *Sclerostachya* (Venkatraman and Parthasarathy, 1942) and *Narenga* (Bremer, 1925) is 30.

INTER-RELATIONSHIP BETWEEN SACCHARUM AND ITS RELATED SPECIES AND GENERA

The several cyto-genetic features exhibited by sugarcane have been published in a series of recent papers (Raghavan 1951-a, b, c, 1952, 1953, 1954-a, b). Leake

(1953) summarising the above papers, points out that the origin of uncertainties associated with *Saccharum* in hybridisation is threefold, and can be traced to high polyploidy, heterozygosity and autosyndesis. To these may be added the recently discovered cytoplasmic inheritance which makes the progeny resemble the mother more than the staminate parent (Raghavan 1951b) making it desirable to bestow more attention on the mother than on the father in sugarcane breeding. Even in the simplest material available, a high amount of genetical impurity is evident and as such orthodox methods of breeding in such a highly heterozygous population are of no avail. Diploid parthenogenesis, absence of haploidy, and the inability to inbreed owing to the operation of lethal factors, and autosyndesis make segregation along Menedelian lines difficult and as such it is almost impossible to break down the high polyploidy. Handicapped by these disadvantages Parthasarathy (1951) attempted to reduce *S. officinarum* to its basic complement ($x=10$) by successfully backcrossing it with the related genus *Sclerostachya.*

(i) *S. officinarum* and *Sclerostachya.*

S. officinarum var. Vellai ($2n=80$) was crossed with *Sclerostachya* ($2n=30$) and the hybrids were repeatedly backcrossed with *Sclerostachya.* Excepting for the first backcross, reduced gametes functioned on both sides in the other backcrosses. In the third backcross, a plant was obtained with $2n=40$ chromosomes made up of 10(0)+30 (S) (0=*officinarum*; S—*Sclerostachya*). In the absence of homology between *S. officinarum* and *Sclerostachya* chromosomes, the normal expectation would be $\underset{O}{10_{i}}+\underset{SS}{15_{ii}}$. However, the meiotic configuration of 20 bodies made up of i.e., $\underset{SSO}{5_{iii}}+\underset{SS}{10_{ii}}+\underset{O}{5_{i}}$ gave the clue that out of the 10 chromosomes of *S. officinarum*, 5 paired with the bivalents of *Sclerostachya* forming 5_{iii}, while the other 5 *officinarum* chromosomes remained as univalents, leaving 20 chromosomes of *Sclerostachya* to pair autosyndetically forming 10_{ii}. It means that out of the basic complement of $x=10$, 5 chromosomes of *S. officinarum* have homology with 5 chromosomes of *Sclerostachya* (Govindaswamy, 1948).

(ii) *Saccharum officinarum* and *Narenga.*

Raghavan (1951-a, c) crossed the 2nd backcrossed progeny of *S. officinarum* x *Sclerostachya* hybrid ($2n=\underset{O}{20}+\underset{S}{30}=50$) with *Narenga*. The meiotic configuration in the mother was as a rule regular forming 25_{ii} indicating autosyndetic pairing $\underset{OO}{10_{ii}}+\underset{SS}{15_{ii}}$. The hybrids with *Narenga* showed 20 bodies at meiosis $(\underset{OSN}{5_{iii}}+\underset{O}{5_{i}}+\underset{SN}{10_{ii}})$. Had the *S. officinarum* chromosomes failed to exhibit any homology with *Sclerostachya* or *Narenga* chromosomes, the normal expectation would be either *$\underset{N}{15_{i}}+\underset{S}{15_{i}}+\underset{O}{10_{i}}$ or $\underset{O}{10_{i}}+\underset{SN}{15_{ii}}$. The latter configuration $(\underset{O}{10_{i}}+\underset{SN}{15_{ii}})$ would indicate an allosyndetic pairing between *Narenga* and *Sclerostachya* chromosomes, which may be a justifiable premise in view of the fact that the F_1 hybrids of *Narenga* x *Sclerostachya* formed 15_{ii} regularly (Parthasarathy, 1947). Instead of the above two expected configurations, the occurrence of 5_{iii} and 5_i seems to point out the homology between 5 chromosomes of *Narenga* and *officinarum*. In other words the three genera *S. officinarum*, *Narenga* and *Sclerostachya* have had a common origin from a putative ancestor, 5 of whose chromosomes are common to all the three (Raghavan 1951 a, c).

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* S=*Sclerostachya.* N=*Narenga.* O=*S. Officinarum.*

(iii) *Saccharum officinarum* and *Sorghum*.

Cytological analyses of certain intergeneric hybrids, i.e., *S. officinarum* x *Sorghum halepense* (Govindaswamy, 1948) have indicated the homology of 2 chromosomes of *Sorghum* with 2 of *S. officinarum* suggesting thereby that these 2 genera have a minimum of two chromosomes in common between them.

(iv) *Saccharum officinarum* and *Saccharum spontaneum*.

In order to study the inter-relationship between *S. officinarum* and *S. spontaneum* the backcross method of breaking up the polyploidy and bringing the chromosomes to the basic level was adopted. The high fertility and the easy crossability contributed greatly to the success of these backcrossings (Raghavan, unpublished).

In the formation of F_1 of *S. officinarum* ($2n=80$) x *S. spontaneum* (Coimbatore) ($2n=64$), unreduced egg functioned on the part of the noble parent, resulting in hybrids with $2n=112$ $(\underset{O}{80}+\underset{Sp.}{32})$ (O=*officinarum*; Sp.=*spontaneum*). This feature is now found to be the rule, whatever *officinarum* may be used as mother. The F_1 was nobilised by using *S. officinarum* as mother. Again unreduced gametes functioned on the *officinarum* side, the resultant hybrids showing 136 chromosomes $(\underset{2n}{80}+\underset{n}{56}=\underset{O}{120}+\underset{Sp.}{16})$. This seedling was crossed with *S. officinarum*, a further stage in nobilization with this difference however, that *S. officinarum* was used as the staminate parent. The offspring showed $2n=108$ chromosomes which is the result of normal fertilization, i.e., $n+n=68+40=\left[(\underset{O}{60}+\underset{Sp.}{8})+\underset{O}{40}\right]$. It may be seen that in the series of crosses, the number of *spontaneum* chromosomes has been successively reduced from 32 to 16 and from 16 to 8 resulting in 100 *officinarum* chromosomes and 8 *spontaneum* chromosomes in the final progeny.

The meiotic behaviour of these hybrids in which the *spontaneum* chromosomes have been reduced to eight, throws light on the basic number as well as homology. In MI 53 bodies were seen made up of $\underset{OO}{45_{ii}}+\underset{OOSp.}{5_{iii}}+\underset{Sp.}{3_i}$. If the 8 *spontaneum* chromosomes had enough homology between themselves, i.e., if the basic number had been 4, instead of 8, they would have formed 4_{ii}, leaving the *officinarum* chromosomes to pair autosyndetically, with the result 54_{ii} would have been observed. It would, however, have meant that the basic complement of 8 is itself made up of two sets of 4 chromosomes. On the other hand, complete lack of homology between *S. spontaneum* and *S. officinarum* chromosomes would have resulted in 58 bodies, i.e., $\underset{OO}{50_{ii}}+\underset{Sp.}{8_{i}}$, in which case all the 8 chromosomes of *S. spontaneum* remain as univalents. The occurrence of 5_{iii} seems to indicate that 5 chromosomes of *S. spontaneum* have paired with 5_{ii} of *S. officinarum* forming 5_{iii} and the rest of the 3 *spontaneum* chromosomes remain as univalents; the 45_{ii} observed are the result of 90 *officinarum* chromosomes pairing autosyndetically.

The chromosomal constitution of the hybrids at successive levels of nobilization is given below. As expected *officinarum* chromosomes assume greater preponderance as nobilization advances.

Variety	Parentage	Chromosome number 2n	Constitution	Thickness of stem	Brix in juice
Green sport		80	O 80	3.5 cms.	17.4
Chittan		80	O 80	3.6 cms.	17.9
S. spontaneum (Coimbatore) (CBE)		64	Sp. 64	0.76 cms.	8.0
Co. 285	G. sport x *S. spont.* (CBE)	112	O Sp. 80 32	1.93 cms.	14.5
P′ 451/1	Chittan x Co. 285	136	O Sp. 120 16	2.14 cms.	14.5
P′ 749/1	P′ 451/1 x Chittan	108	O Sp. 100 8	2.25 cms.	14.7

(v) *S. officinarum*, *S. robustum*, *Sclerostachya* and *Narenga.*

Brandes and Sartoris (1936) record that "when a noble cane is crossed with *S. robustum*, there is an increase of chromosomes above the number which corresponds to the sum of the monoploid numbers of the parents, but it is considerably less than the diploid number of *S. officinarum* and the monoploid number of *S. robustum*". According to them, 32 chromosomes of *S. robustum* pair allosyndetically with 32 chromosomes of *S. officinarum* and the remaining chromosomes of both the parents get doubled. The hybrids thus, instead of having n+n (40+42)=82, have 2n=100 which may be represented as follows : $\underset{O}{32}+\underset{R}{32}+\underset{OO}{(8\times 2)}+\underset{RR}{(10\times 2)}=100$ (O=*S. officinarum*; R=*S. robustum*). Accordingly this would seem to indicate that auto as well as allosyndesis take place in these hybrids. Grassl (1946) summarising the results, points out the following main reasons for considering *S. robustum* as being closely related to *S. officinarum.*

(*i*) The occurrence of chromosome number in multiples of 10 in both these groups.

(*ii*) The increase of about 18-20 chromosomes in *S. officinarum* and *S. robustum* hybrids "which is only about one-half as great as when *S. spontaneum* is used as the male parent" (against *S. officinarum*) and consequently it is surmised that *S. robustum* and *S. officinarum* possibly have as many as 20 chromosomes in common.

(*iii*) The absence of IV glume in both *S. robustum* and *S. officinarum*.

(*iv*) Some of the 'noble' canes from Micronesia and Polynesia, resemble very much the artificial hybrids between *S. officinarum* and *S. robustum*.

The morphological characters of the hybrids between *S. officinarum* and *S. robustum* produced at this Station reveal the characters of both the parents even though they are more disposed towards the mother presumably because of the influence of the maternal cytoplasm (Raghavan, 1952; Sundararaghavan, 1954). There seems to be little doubt about the hybrid nature of these seedlings. The male parent (*S. robustum*) has a fertility of 90 to 96 percent while the mother Vellai is male-sterile. The hybrids, however, have a fertility of 60 to 70 percent. The hybrids produced here have come into being through the functioning of haploid gametes $(40_{O}+42_{R})$ (O=*S. officinarum*; R=*S. robstum*), a fact which is corroborated by the findings of Li and Shang (1951). It has been suggested by Parthasarathy (1946) that "reduced gametes function, when genetic relationship is close, but unreduced gametes function when the two species are distantly related". In this connection it may be pointed out that whenever either *S. Barberi* or *S. spontaneum* is used as male on *S. officinarum*, only diploid gametes are contributed by the mother (Raghavan, a, c). In other words, the functioning of n or 2n eggs on the part of *S. officinarum* has a direct bearing on the staminate parent. Even though the functioning of reduced or unreduced egg cannot be taken as an unfailing indication of genetic relationship, yet the behaviour of *S. officinarum* can be utilised to some extent to determine genetic relationship. The functioning of normal haploid gametes in the cross *S. officinarum* x *S. robustum* almost as a rule and vice versa, may be taken as a fair indication of their affinity.

Additional evidence seems to be forthcoming through a study of *S. robustum* x *Sclerostachya* and *S. robustum* x *Narenga* hybrids. In the hybrids between *S. officinarum* ($2n=80$) and *Sclerostachya* ($2n=30$), the F_1 shows $2n=55$ (being the product of normal fertilization). The meiotic configuration is $25_{ii}+5_{i}$ (Govindaswamy, 1948). The 5 univalents because of their larger size, could be identified as belonging to *Sclerostachya* indicating that the chromosomes of *S. officinarum* pair by means of autosyndesis forming 20_{ii}, while the haploid complement of *Sclerostachya* forms $5_{ii}+5_{i}$. In the three sets of 5 chromosomes each making up the haploid complement of *Sclerostachya* only two sets are homologous enough to form bivalents autosyndetically while the third set remains unpaired as univalents The absence of any other association than those of bivalents indicates that the third set of 5 chromosomes, is non-homologous with either of the other sets.

In the hybrids of *S. robustum* x *Sclerostachya* and *S. robustum* x *Narenga*, the most common meiotic configuration is $26_{ii}+5_i$, while chromosomes of *S. robustum* pair autosyndetically forming 21 bivalents, the *Sclerostachya* complement forms $5_{ii}+5_i$. However, the occurrence of 28 bivalents and 1 univalent in some cases seems to indicate that the third set of 5 chromosomes of *Sclerostachya* pairs allosyndetically with *S. robstum*. The occurrence of $28_{ii}+1_i$ may be due to either of the two following configurations :—

$$^{*}\ \underset{RR}{18_{ii}}+\underset{SS}{5_{ii}}+\underset{RS}{5_{ii}}+\underset{R}{1_i} \quad \text{or} \quad \underset{RR}{19_{ii}}+\underset{SS}{5_{ii}}+\underset{RS}{4_{ii}}+\underset{S}{1_i}$$

Either way, it indicates partial allosyndesis between 4-5 chromosomes of *Sclerostachya* and *S. robustum*. The same conclusion is reached from the study of *S. robustum* x *Narenga* hybrids. It may be pointed out that Janaki Ammal (1942) while studying *S. officinarum* x *Narenga* hybrids, has observed a maximum of 2_{iv} and 2_{iii} thereby suggesting allosyndesis between *S. officinarum* and *Narenga* chromosomes. Also in the hybrids of *S. robustum* x *S. officinarum*, *S. robustum* x *Sclerostachya* and *S. robustum* x *Narenga* trivalents and quadrivalents are seen which may be due to the allosyndetic pairing of *S. robustum* chromosomes with the chromosomes of the other parents.

In the light of the above observation *S. robustum*, *S. officinarum*, *Sclerostachya* and *Narenga*, seem to have 4-5 chromosomes common between them. Since it has been established that *Sclerostachya* and *S. officinarum* are closely related, it is not surprising that *S. robustum* should show affinity to *Sclerostachya*. After all, *Sclerostachya* is not a distant genus in the same sense as Coix, Maize or Teosinte are and as such it is likely to have played an important role in the origin of *S. officinarum*. In fact the affinities between *S. robustum* and *Sclerostachya* seem to confirm indirectly the close relationship between *S. robustum* and *S. officinarum*. Both *S. officinarum* and *S. robustum* have many important characters common between them, such as size, easy shedability of the leaves, the absence of the 4th glume and the absence of the internodal starch (Dutt and Narasimhan, 1950). There are, however, some differences between the two in morphological features. For example, the spikelets of *S. robustum* are smaller than those of *S. officinarum*; there are minor differences between the two species in the venation of the glumes also. It might be that both *S. robustum* and *S. officinarum* may have had a parallel evolution. While hybrids with *Sclerostachya* as mother and *officinarum* as staminate parent are impossible to get, the readiness with which *S. robustum* has crossed with *Sclerostachya* as the pistillate parent seems to indicate that *S. robustum* is the more primitive of the two.

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*R=*S. robustum*; S=*Sclerostachya*

(vi) *Saccharum robustum* and *Saccharum spontaneum.*

S. robustum differs from *S. spontaneum* in the absence of the 4th glume, the sparser and shorter nature of the hairs on the main axis of the inflorescence, the broader and larger nature of the inflorescence, and the smaller size of the spikelets. However, the polyploid nature of these species in multiples of 8 or 10, the aneuploid nature of certain clones, and lower sugar content seem to suggest probable affinities between the two.

It is worthy of note that in spite of repeating the cross for 3 years, only 2 seedlings were derived between *S. robustum* × *S. spontaneum*, while the reciprocal cross failed to yield any seedlings at all. Significant also is the fact that while *S. robustum* crosses readily with *Sclerostachya* or *Narenga*, few or no hybrids are got with *S. Spontaneum*, in spite of the high degree of fertility in both these species. The two hybrids of *S. robustum* ($n=42$) × *S. spontaneum* ($n=32$) have been derived through the functioning of $n+n$ gametes $[(2n=42+32)=74]$.

Apart from the genera dealt above the genus *Erianthus* also seems to have played a part in the evolution of the noble cane. Grassl (1946) is of the opinion that *E. maximus*, might have been the ancestor of cultivated *Saccharum*. According to him, "the noble canes are more closely related to *S. robustum* and *Erianthus maximus*. There may have been separate origins of sweet forms in both these groups but it seems more likely that the main origins were from *S. robustum*". The main support for the above view (i.e., from *E. maximus*) is the presence of an awned 4th glume in some of the *S. officinarums*. It may be, however, added that besides the Mungo group of *S. Barberi*, *Saccharum officinarum* × *Sorghum* hybrids as also some of the *Sclerostachya* × *Narenga* hybrids possess awned 4th glumes—probably a case of reversion. As such the presence of awn cannot be taken as a sure indication of close relationship. Similarly the resemblance between *E. arundinaceus* and the cultivated noble canes in some morphological characters has been advanced as proof of inter-relationship between the two. The non-flowering nature of *E. arundinaceus* has so far stood in the way of effecting crosses and obtaining cytogenetic evidence in this regard.

ORIGIN OF SACCHARUM BARBERI

Chromosomal studies in the genus *Saccharum* have pointed out the capacity of *S. officinarum* and *S. spontaneum* to produce haploid as well as diploid eggs, the functioning of 2n eggs being a postmeiotic phenomenon. Narayanaswamy (1940) is of the view that the fusion of 2 megaspores in a linear tetrad, leads to diploid egg formation, while Bremer (1949) thinks endomitosis in the chalazal megaspore of the linear tetrad as being responsible for this. In either case, it is post meiotic and as such even parthenogenetic derivatives from such diploid eggs, show neither uniformity among themselves nor identity with the mother. Besides this *S. officinarum* is capable of contributing egg gametes having neither the diploid nor the haploid number (through accessory spindle formation and consequent elimination of chromosomes *en bloc*) (Subramaniam 1946;

Parthasarathy 1946, 1951 ; Raghavan 1954-a, b).

Co. 421 (2n=118) was observed to give rise to two kinds of eggs, viz., 86 and 118 respectively, each capable of developing parthenogenetically. The seedlings derived from the former resembled the North Indian canes in morphological features. Struck by the close resemblance between these and the *S. officinarum* x *S. spontaneum* hybrids such as Co. 205, Co. 206, Co. 285 and Co. 291, to the North Indian canes, Parthasarathy (1946) suggested the origin of *S. Barberi* from *S. officinarum* through natural hybridisation with *S. spontaneum.* In morphological characters such as stem thickness, nature of leaves, root system and mode of tillering North Indian canes are intermediate between the two. In the floral characters, there is a mingling of characters of both the parents, with a preponderance of *spontaneum* characters. In features, such as sucrose content, fibre content and resistance to diseases, *S. Barberi* occupies an intermediate position. The mode of underground branching clearly indicates their hybrid origin (Barber, 1916). The presence of ligular process is a character inherited from *S. officinarum.* In fact throughout the memoirs of Barber, there is a vague suggestion about the hybrid origin of the thin canes; he did not express it because he believed that *S. officinarum* was not indigenous to India. Substantial support to this view is lent by the discovery by Mukerjee (1949) of natural hybrids between *S. officinarum* and *S. spontaneum* in a wild state in the north east regions of India where it is most likely, this impact has taken place.

The high fertility of the hybrids and the parents, as well as the functioning of diploid eggs and eggs with varying numbers, would have permitted free intercrossing and backcrossing, resulting in hybrid swarms. Geographical isolation, would account for the diversified sub-groups each with specific chromosome numbers. Accepting the above view would mean that *S. officinarum* is not foreign to India, but was actually present earlier than *S. Barberi*, having been responsible for its origin.

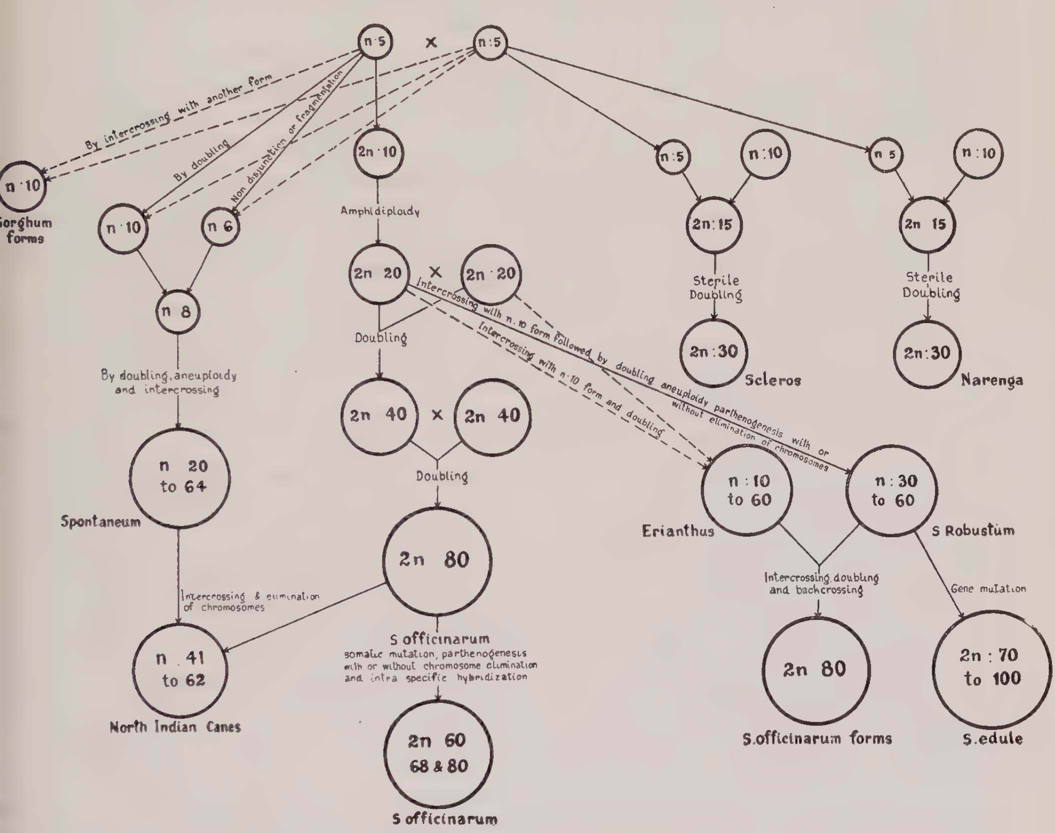
SUMMARY AND CONCLUSION

In the light of evidence available so far, the probable phylogeny of *Saccharum* and related genera has been represented diagrammatically.

It may be considered that *Saccharum* and its related forms have originated from a common ancestor with a basic complement of 5 chromosomes ($x=n=5$). This putative ancestral form might have crossed with another 5-chromosomed-form resulting in sterile hybrids presumably because of differences in structure though not in number ; escape from sterility was effected through amphidiploidy. Intercrossing and backcrossing to the parents presumably led to different lines, each stabilizing itself at particular chromosomal levels. A study of the chart reveals how *Saccharum*, *Sclerostachya* and *Narenga* have had a common origin in respect of 5 chromosomes.

From the n=5 type, two forms might have come into existence one with n=10 and another with n=6, the former by a process of doubling and the latter, either by nondisjunction or fragmentation resulting in a secondarily balanced number. These two by further intercrossing would give rise to x=8 forms, which by intraspecific hybridisation polyploidy and aneuploidy might have

HYPOTHETICAL PHYLOGENY OF SACCHARUM AND ALLIED GENERA


n 5
×
n 5
By intercrossing with another form
By doubling
Non disjunction or fragmentation
n 10
orghum forms
n 10
n 6
n 8
By doubling, aneuploidy and intercrossing
n 20 to 64
Spontaneum
Intercrossing & elimination of chromosomes
n 41 to 62
North Indian Canes
2n 10
Amphidiploidy
2n 20
×
2n 20
Doubling
2n 40
×
2n 40
Doubling
2n 80
S officinarum
somatic mutation, parthenogenesis with or without chromosome elimination and intra specific hybridization
2n 60 68 & 80
S officinarum
Intercrossing with n 10 form followed by doubling aneuploidy parthenogenesis with or without elimination of chromosomes
Intercrossing with n 10 form and doubling
n 5
n 10
2n 15
Sterile Doubling
2n 30
Scleros
n 5
n 10
2n 15
Sterile Doubling
2n 30
Narenga
n 10 to 60
Erianthus
n 30 to 60
S Robustum
Intercrossing, doubling and backcrossing
2n 80
S.officinarum forms
Gene mutation
2n 70 to 100
S.edule

resulted in diversified groups showing intergrading numbers. Such a method as postulated above, seems to be the basis for the origin of the various *spontaneums*.

Two views can be advanced for the origin of the *officinarums*; either both *Saccharum officinarum* and *Saccharum robustum* have had a common origin or the latter gave rise to the former :—

(i) According to the first suggestion, it would mean that *S. officinarum* and *S. robustum* should have diverged at the 2n=20 level. The 2n=20 forms would have crossed with forms with an indentical chromosome number but a structurally different genomed type to give rise to sterile hybrids. Amphidiploidy and further intercrossing followed by doubling will result in octoploids. On the other hand, *S. robustum* taking a different line from that of *S. officinarum* at the 2n=20 level would by a similar process have given rise to higher polyploids which by means of diploid parthenogenesis preceded by elimination of chromosomes or not resulted in aneuploids and lesser polyploids. The different chromosomal races of *S. robstum* found are presumably a result of these cytological phenomena. (ii) If we regard *S. robustum* as having given rise to *S. officinarum* then the origin of the noble canes has to be explained differently. From the 2n=20 ancestor evolution proceeded along two different lines, one culminating in *S. robustum* and the other in *Erianthus*. Sweeter forms presumably arose from *S. robustum* and these through natural hybridisation with species of *Erianthus* such as *Erianthus maximus* and further backcrossing with *S. robustum* probably resulted in the noble canes, improvement of which was mainly by further selection.

Once the different lines of evolution of *S. officinarum*, *S. spontaneum* and *S. robustum* are established, it is easy to postulate the origin of *S. Barberi* and *S. edule*. Gene mutations in *S. robustum* presumably resulted in *S. edule*, which because of its pulpy and abortive inflorescence passed off for a new species of *Saccharum* (Lennox 1938). The above assumption is based on the fact that *S. edule*, except for minor variations such as the presence of a velvety leaf blade, and absence of so hairy a sheath, differs very little from *S. robustum*.

In sub-tropical India, in the regions of Bihar, Bengal and Orissa, natural hybridisation between *S. officinarum* and *S. spontaneum* probably laid the foundation for the origin of *S. Barberi*. The presence of naturally occurring hybrids between *officinarum* and *S. spontaneum* recently discovered by Mukherjee (1949) lends substantial support to this theory of the probable origin of *S. Barberi*. The origin of the various chromosomal sub-groups of *S. Barberi* is traceable to the capacity of *S. officinarum* to contribute besides haploid and diploid eggs, gametes with unexpected chromosome numbers also through elimination of chromosomes *en bloc*. Apparently these two opposing processes of chromosome eliminations on the one hand and chromosome multiplication on the other hand, through endomitosis, both acting side by side paved the way for the origin of new chromosomal races with a high range of variability suited to the various geographical areas. The evolution of North Indian canes with unrelated chromosome numbers can be explained on the basis of the above phenomenon. The new races possibly stabilised themselves in the different tracts and were geographically isolated from one another. Where the geographical isolation broke down, intercrossing between the various sub-groups presumably took place resulting in newer hybrids. In some of the groups, isolation favoured the accumulation of genic differences to such an extent as to render these groups distinct from one another; this is evidenced by the wide range of fertility (from highly fertile Saretha group, to completely sterile Mungo group) in these various forms.

With the data on hand, it would appear that in the phylogeny of *Saccharum*, polyploidy, interspecific and inter-generic hybridisation and apomixis appear to have played a more important role than gene mutation and structural changes. The above picture is only tentative subject to revision in the light of further knowledge that future findings may throw.

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DISCUSSION

Dr. Chilton enquired how Dr. Raghavan distinguished seedlings showing maternal inheritance from those derived parthenogenetically. Dr. Raghavan replied that parthenogenesis was confined to selfing and where distant genera were involved.

Dr. T. S. Venkatraman expressed surprise that only two sugarcane x bamboo hybrids were raised in the repeated sugarcane x bamboo cross. One of the bamboo hybrids raised by him, he said, looked like a sugarcane but gave a dark juice, containing a large quantity of tannin apparently derived from the bamboo parent.

GROUP V

TAXONOMY AND BIOSYSTEMATIC

The Chairman requested Dr. Tysdal to present Dr. E. W. Brandes' paper.

Paper

ORIGIN, DISPERSAL AND USE IN BREEDING OF THE MELANESIAN GARDEN SUGARCANES AND THEIR DERIVATIVES, *SACCHARUM OFFICINARUM* L.

E. W. Brandes

United States Department of Agriculture, U.S.A.

INTRODUCTION

The present paper on the origin, dispersal and use in breeding of a kindred aggregation of *Saccharum* forms, here designated as garden sugarcanes of Melanesia and their derivatives, and variously called "thick-stemmed tropical", "original" or "noble" sugarcanes, also broadly interpreted as the horticultural species *S. officinarum* L. (Frontispiece), (1) is the fourteenth technical

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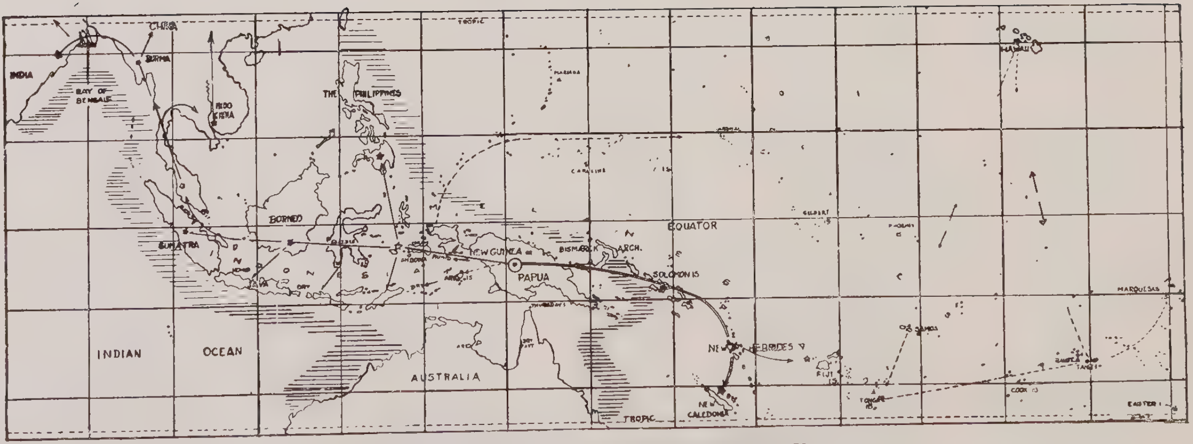
(1) Although no type specimens exist there is good evidence that Linnaeus based his species *officinarum* on the only sugarcane readily available to him, now known as Creole. The clone gradually disappeared from extensive cultivation between 100 and 150 years ago. Much historical and botanical study has beeh devoted to the clone by Deerr (22), Bremer (19),Grassl (27) and others, but there remains some confusion as to its identity and synonymy. By an unusually fortunate circumstance the U. S. Patent Office published in 1849 a contemporary series of technically correct and beautifully executed drawings of Creole made by Charles L. Fleishmann of Philadelphia (26). Fleishmann was assisted in this work, which includes


INDIA
BAY OF BENGALE
CHINA
BURMA
INDO CHINA
THE PHILIPPINES
BORNEO
SUMATRA
JAVA
NEW GUINEA
PAPUA
BISMARCK ARCH.
SOLOMON IS
EQUATOR
NEW HEBRIDES
NEW CALEDONIA
FIJI IS
TONGA IS.
SAMOA
COOK IS
TAHITI
MARQUESAS
EASTER I.
HAWAII
INDIAN OCEAN
AUSTRALIA
TROPIC
TROPIC
Derived From S. robustum Ca. 8000-15000 B.C. ⊙
First Track Of Migration Ca 8000 B.C. ET SEQ
Second Tracks Of Migration Ca 6000 B.C. ET SEQ
Third Tracks Of Migration Ca 600-1100 AD
Satellite Centers Of Diversity Along Tracks Of Migration ★

ORIGIN, MIGRATION & DIVERSIFICATION - CENTERS OF NOBLE SUGARCANES

ANCIENT MIGRATIONS COVER HALF THE CIRCUMFERENCE OF THE EARTH contribution stemming from a comprehensive sugarcane project, the gathering of world reference collection of ancestral or precursor wild and domesticated cane varieties begun in 1922.

The contributions include separate treatments of the more or less discrete segments of the reference collection on the subjects of comparative morphology (1, 2, 3, 4, 5, 6, 7, 27), disease reactions (12, 14), geographic origins based on the ranges of wild forms and centers of diversity of domesticated forms related to them (13, 14, 16), ecological diversity and adaptation (17), and of course practical cane breeding (12, 14), which is the central theme of the project.

The conception of the over all project grew out of the need in the United States for locally adapted, disease-resistant genotypes and was based on observations leading to an uncomplicated idea, namely that in general, groups of the original *Saccharum* forms related morphologically and particularly groups of individuals related both in form and in geographic origin are apt to have functional characteristics in common (12). In other terms, the mode of the phenotype often but not invariably reflects the mode of the genotype in physiological qualities including such puzzling characteristics as group adaptability to alien environments and even group reactions to infections.

In fact, observations on the group reactions of morphologically related *Saccharum* forms to sugarcane mosaic virus (10, 12) stimulated the concept of gathering from their primary, isolated areas of origin all cultivated and wild groups of *Saccharum* and *Saccharum* relatives and assembling them for comparative study at each of several stations at different latitudes in the New World. Duplicating the reference collection in that manner was for the purpose of studying adaptability and insuring the production of normal specimens. The expectation was that every variety in the collection would be found naturally adapted to the photoperiod and other natural elements of the environment in at least one station (17).

The garden sugarcanes of Melanesia and their descendents elsewhere from transported migrant plants constitute the original and by all odds the most important base from which our present cultivated hybrid varieties derive. These forms comprise a large part of the assembled reference collection. As background material and to promote fullest interest in use of this extensive store of germplasm, what is known or what logically may be inferred concerning the history, value and use of these varieties as a group and their interrelationships with other discrete varietal groups are here placed on record.

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enlargements of microscopic features of the clone "Otaheite", by the internationally famous Czech botanist Corda. Corda was recommended for this scientific investigation by Baron Alexander von Humboldt. The morphological characteristics of Creole, a short, relatively thick-stemmed greenish yellow cane with erect leaves, are quite distinctive. The clone proved to be extremely susceptible to mosaic and is practically extinct. These excellent drawings of Creole showed that our own specimens from Santo Domingo and Spain, which had to be destroyed because of mosaic infection, were authentic.

The practical purpose of the overall project was to try to provide a broader base of knowledge for applied research on the improvement of sugarcane by breeding, taking into account the elementary characteristics of the plant groups that could be determined by observation, tests or planned experiments. Regarding the particular group under reference in this paper it is part of our purpose to direct attention to the exploited and still unexploited values in the largely untapped reservoir of garden canes. This will be developed under the topics (1) importance of *S. officinarum*, (2) colloquial names, (3) relative position of *S. officinarum* in the genus, (4) origin and dispersal, (5) collecting expeditions 1853-1951.

IMPORTANCE OF *S. OFFICINARUM*

The indispensable sugar-bearing component of essentially all of the numerous and widespread varieties of domesticated sugarcane, which form a complex of polyploid hybrids, is provided by a few selected representatives of the tropical, thick-stemmed horticultural species *S. officinarum.* The high weight per cane, self-cleaning or de-leafing of the cane and the high tonnage per acre of the crop are also directly endowed by the same selected representatives of the tropical garden canes under reference in this paper. Less generally recognized but nevertheless important qualities found within the species are resistance to some formidable diseases and, considering the tropical origin, a surprising degree of adaptability to harsh alien climates. In addition to these cultural qualities practically all qualities that facilitate the processing of sugarcane in mills, low fiber content, high purity of juice, i.e. a high proportion of sucrose in the total solids of the parenchyma (storage) cells and a low proportion of invert sugar, starch, etc. are found in the *S. officinarum* genotypes. In short, the *S. officinarum* parent provides all the characteristics esteemed in field and factory which establish sugarcane in adapted areas of the tropics and subtropics as an economic plant *par excellence* for production of sugar. Of necessity in breeding sugarcane for better adaptation to temperate zone conditions and fo resistance to maladies like mosaic and root rot, *S. officinarum* forms have been hybridised with other species notably the mosaic-resistant *S. spontaneum* L. In the days before planned hybridisation such crosses apparently took place under natural conditions and the horticultural species *S. sinense* Roxb. and *S. barberi* Jeswiet may have arisen in that manner (33). It is fortunate that in the one-sided doubling of chromosomes which frequently has been known to occur in the hybrids of *S. officinarum* × *S. spontaneum* it is the *S. officinarum* chromosome complement which doubles (18). Some of the resulting seedlings are not only resistant to certain diseases and better adapted to some Temperate Zone environments fringing the tropics but they possess almost undiminished the desirable qualities of *S. officinarum.*

COLLOQUIAL NAMES

In comparatively recent years several collective names descriptive of the origin, appearance or use of the numerous and variable varieties, or more properly *clones*, of *S. officinarum* have found their way into sugarcane literature. These collective names coined during the early decades of the present century are convenient and reasonably definitive although, as often happens, more and more restricted or extended meanings have been attached to them as they gained currency in the writings of later authors.

In the former Netherlands East Indies they have been referred to as the original sugarcane varieties (oorspronkelijke Rietsoorten) in distinction from the new seedling varieties produced in prodigious numbers by *planned* cane breeding at modern experiment stations. Jeswiet (28) and Posthumus (34) made clear that in using the term they referred to the domesticated tropical sugarcanes selected and cultivated for chewing by the indigenous peoples of the "Malay Archipelago". Posthumus took pains to explain that the term original did not necessarily imply *ancient*, or that this category of canes is not enlarged also at the present time in Indonesia, however inconspicuously, by continued selection of chance seedlings. The distinction between original sugarcane varieties and other categories of varieties seemed valid and useful. Extension by Bremer (19) of the term "original" to include another category of domesticated canes, namely the predecessors in northern India of the Coimbatore and other modern seedling varieties, is logical but confusing. The evidence makes clear that these canes also were not created by purposeful hybridisation but represent selections from chance natural hybrids. Bremer modified the term original by adding a place name, calling them the "oorspronkelijke Britsch-Indisch Suikkerrietsoorten" (original British Indian sugarcane varieties). Further modification of the place name by eliminating "Britsch" is now obviously necessary. Carried to its logical conclusion the extension of meaning as used by Bremer would result in a long series of related but more or less discrete original sugarcane groups that came into existence prehistorically by promiscuous hybridisation or selfing along the track of the migrating original sugarcanes from the Melanesian archipelago.

Another widely accepted alternative name for the varieties of *S. officinarum*, noble canes, coined or adopted from the English language by the Netherlanders in Java about 1920 is an obvious reference to their flamboyant colours and large size in striking contrast with the drab colours and unprepossessing appearance of most canes of other species. Unlike the term original, the term noble carries no implication of the precursory nature of *S. officinarum* relative to all domesticated sugarcanes but the identity of the group referred to is fairly well understood and there is little likelihood that the word will be misappropriated for other groups of cane. There is in sugarcane literature a lack of unanimity among writers in the use and meaning of cognates derived from the expression noble canes, i.e. nobilize, nobilization, etc. As first used the sense of nobilize was simply to improve or ennoble the wild *S. spontaneum* forms or forms of other groups by hybridising them with *S. officinarum.* In recent literature e.g. contributions by H. W. Li (31) nobilize implies more specifically the increase in chromosome numbers of species hybrids resulting from the one-sided doubling of the *S. officinarum* complement.

The few individuals who have collected *S. officinarum* varieties first hand in the New Hebrides, Solomon Islands, New Guinea and adjacent smaller islands of Melanesia are inclined to use the collective name native garden sugarcanes of Melanesia or simply native sugarcanes of this or that island. They are in fact the only *native* domesticated sugarcanes in the sense that among the whole world's array of cultivated sugarcanes they are the only ones that were wholly developed, in place, from indigenous wild ancestral forms. The concept of *S. officinarum sensu* Jeswiet does not exclude the numerous forms derived from and closely resembling the native garden sugarcanes of Melanesia but long established in native cultures of Indonesia, Indo China, the Philippines, and Polynesia. In fact, the majority of individual clones listed by Jeswiet in 1925 as typical of *S. officinarum* belong to that category, a circumstance attributable no doubt to the fact that until 1928 Jeswiet was unfamiliar with the far richer assortment of forms in New Guinea. All of the collective names mentioned are suggestive of one or more characteristics peculiar to the *S. officinarum* type of cane. When used colloquially with discrimination they identify the type of cane referred to.

Reconciling the synonymy of the numerous colloquial and vernacular names of the multitude of *individual clones* of *S. officinarum* presents almost unsurmountable difficulties. The difficulties are of two sorts, the occasional use of the same name for several different clones and the almost universal and unavoidable renaming of the same clone times without number if it happened to be an adaptable, globe girdling sort. The practice of renaming has been most active during the past 100 years but, with more penetrating retrospection, it is safe to infer that the renaming habit was very old a century ago.

Let us by inference trace from the beginning the renaming of a clone. When an individual clone comes into existence, say on some river bank in New Guinea near a garden from which the seed has blown, and is selected for some good quality and established as an entity, an identifying name is given to it in the dialect of the village. If the variety proves exceptionally desirable it is carefully weeded and cuttings may be taken to a daughter village of the same clan or tribe. Eventually the variety finds its way to a village in the next valley where the language is different. Step by step over a long period of time it completes a journey to the coast. Meanwhile the variety has been renamed innumerable times for various reasons. Sugarcane is among the recognized spoils of tribal warfare and in the confusion of a typical retaliatory raid usually in the darkness before dawn the booty is seized but of course the identifying name is lost. It is characteristic of sugarcane varieties the world over that they do not long remain nameless. Perhaps the next stage in the wanderings and rechristenings of our variety is when it is taken by Malay prau from the coast to the nearby Aru Islands or Amboina, both ancient trading and distribution centres, thence in the couse of time possibly to Celebes or Borneo.

If our hypothetical variety started the second stage of its long migration during the past four centuries, it encountered not only dialects of entirely different families of "native" languages in these islands but several Chinese and European languages as well. The variety, being an exceptionally desirable one, had been increased long since to large proportions. Its progress into new territory would be represented on a chart like the branches of a tree rather than by a single line. This normal development generated confusion compounded and in the far flung islands of Indonesia the variety had many names at the same time. The names at this time usually represented the last stopping places on its multiple pathways, a fact easily verifiable by studying the local vernacular names transliterated into Dutch. This fact also tends to prove that the variety was not indigenous at its place-name. The authentic indigenous names never refer to places. Bandjermasin hitam-riet did not originate at Bandjermasin nor Zwart Cheribon at Cheribon. The natural officinarum x local spontaneum hybrid Kassoer (not a place-name) apparently *did* originate near Cheribon, a stopping place on the pathway of the officinarum parent.

European infiltration of the archipelago contributed to the plurality of names of our variety when Spaniards, Portugese, Netherlanders, Frenchmen, Britons and others ushered in the epoch of its grand tours to the New World. The hazards of transportation in relatively modern sailing vessels prompted some of the renaming. Among other hazards, not the least were the moulded, mutilated, or lost identification tags in shipments. Louisiana Purple, a rather stable (but not immutable) clone, very likely has had more than 100 names since some frizzly-haired horticulturist armed with a black palm dibble and happily making anticipatory sucking noises with his mouth thrust a leafy top-cutting from a purple river bank seedling into his garden soil.

Most of the name changing of the old migratory *S. officinarum* varieties was unavoidable or at least understandable. Some of it was arbitrary and inexcusable. A flagrant example is afforded by the wholesale renaming of 60 original varieties of New Caledonia about 1866 by de Greslan cited by Sagot and Raoul (35). According to Sagot, de Greslan who had prepared an excellently illustrated monograph on the varieties with locations and indigenous names later "named each of the canes after a well-known person of New Caledonia." Sagot published an abstract of the monograph prepared at his request by de Greslan himself but he deplored the new names and did not repeat them in his book. Some of them, however, persist. Prof. F.S. Earle published an annotated list of 1700 names that have been applied to cane varieties (25) of which nearly 1500 appear to relate to the *S. officinarum* garden sugarcanes. Unquestionably, he says, many of the names are synonyms due to the pernicious custom of renaming varieties. We have endeavoured to show in the foregoing paragraphs that in the past most renaming was due to the force of circumstances and no amount of admonishment could have prevented it.

Fortunately, improved communications today will help to retard the duplicating of names for the same clones but the problem of cane variety synonomy remains. Solution of the problem can be advanced only by careful standardized taxonomic studies such as those in progress on fairly large samplings of the *S. officinarum* clones at the present time. The clones important because of outstanding superiority and adaptability which should be given priority in such studies, represent only a small proportion of the total number. These nevertheless present the greatest problem as they have been given the largest number of names.

RELATIVE POSITION OF *S. OFFICINARUM* IN THE GENUS

The question of speciation in the genus *Saccharum* is too complex and specialized to be discussed at length in this paper, but a few observations on plant genetics may help to explain some of the barriers preventing clear-cut separation of *S. officinarum* varieties from those of other species. Conversely, their assumed genetic history may explain the existence of some modal characteristics of these varieties that help to distinguish them from others.

A comparison with other kinds of plants (for example the near relative Sorghum) in which there is more normal, clear-cut separation of a genus into several species will help to make plain the barrier referred to. To emphasize the comparison we take liberty to simplify and idealize the facility of separating species in the kinds of plants used for comparison. In simplest terms such plants in common with all plants and animals exhibit *diversity* or small variations among the individuals (the basis for organic evolution) but they also exhibit *discontinuity* of variation, that is, instead of a continuous series of small variations there will occur clear-cut separations in which the variation may be abrupt and pronounced, followed on a different level by resumption of the small variations between individuals then by another abrupt separation, and so on. This is typical of plants which reproduce regularly by seeds resulting from frequent interpollination (sexual exchange of genes) between the closely similar individuals of each level but not between the less closely related individuals of different levels.

Cytogeneticists have explained the incompatibility between levels (species) on the basis of nature's devices called isolating mechanisms which prevent the consummation of mating between the different strata (36). Up to the present, eight categories of reproductive isolation have been described. Isolation by different reproductive seasons at a given locality may be cited as one of nature's devices to prevent mating of *S. officinarum* and "long day" forms of *S. spontaneum* which a few sugarcane breeders have circumvented by carrying the pollen on airplanes to flowering mother plants perhaps 2,000 miles away (15). In general, the species are maintained and kept separate by mutual exchange of genes entirely within the isolated pool of genes governing the hereditary characteristics of the particular species. The plasticity of a species, i.e. its store of potential variants and its ability to adjust gradually to changing external conditions, is not impaired by this arrangement nor is there impairment of discontinuous variability.

The fact of discontinuity of variation in sexually reproducing organisms is apparent to anyone who has observed the similar yet undeniably different species of bears in a zoo and the fact can be accepted without going into the prolix explanation.[1]

Taxonomists have made use of the discontinuity of variation to create an elaborate system for natural classification of plants, separating them into races, species, genera, tribes, families, etc., in an ascending hierarchical order of relationships based on morphology of the flowers.

BARRIERS PREVENTING CLEAR-CUT DEFINITION OF DOMESTICATED "SPECIES"

Nature, however, has provided some exceptions not fitting entirely or precisely into the natural classification system. Modification of sexuality or substitutions in whole or in part for the typical sexual method of reproduction are found in some familiar plant groups including sugarcane. Sugarcane is made up of an aggregation of facultatively asexual and obligatorily asexual members complicated by potentialities in some members for wide hybridisation. To a greater or lesser extent some of the reproductive aberrations tend to obscure the normal discontinuity of variation and therefore confuse the boundaries of species.

The conditions preventing clear-cut separations between some species of *Saccharum* are more puzzling in the cultivated groups or "species" *officinarum*, *sinense* and *barberi* than in the wild growing species *spontaneum* and *robustum*. The sexual conditions or deviations are several, including (1) high-polyploidy which makes possible in nature some species interbreeding and, rarely, wide hybridisation even with grasses of other genera, (2) self-fertilization, (3) vegetative propagation of cultivated varieties or clones for centuries of time with attendant mutations in many unstable clones, (4) male sterility, (5) incompatibility of the male and female gametes, and (6) in many clones absence of floral organs because of abortive or completely lacking inflorescenses, making vegetative reproduction obligatory. We refer to non-flowering due to innate sterility as well as the more common failure to flower of some migrant forms in alien uncongenial environments.

The consequences of this combination of deviations from typical sexuality, i.e., frequent random matings in closed systems, are, in the domesticated original sugarcanes, the development of a miscellaneous assortment of moderately definable groups each composed of individuals with some characteristics in common and the development of more numerous odd or intergrading forms interspersed in and between them. Individuals of fairly well-defined groups of sugarcane owe their homologies partly to spatial or geographic isolation of long duration following prehistoric migrations of *S. officinarum* to islands, for example extensions into New Caledonia, certain islands of Indonesia, Hawaiian Islands and the Philippines, all more or less remote from the rather restricted natural range in Melanesia of the assumed principal ancestral form, *S. robustum*. Separated from the wild ancestral form a part of the evolutionary plasticity was lost to these groups. Together with the numerous odd forms the groups constitute a complex of highly polyploid mutants and hybrids.

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(1) Hybrid bears have been produced in the Smithsonian Inst. Zoological Garden at Washington, D.C., but lkie mules they are sterile.

In attempting to erect species like those found in sexual groups for the accommodation of all members of this sugarcane complex, taxonomists have not been able to agree in the past even on generic separations. With gradual accumulation of living and herbarium plant material and continued careful study in field plots there have been revisions of the genus *Saccharum*. The last and most generally acceptable revision is that of Jeswiet (29) which rejects many species and sets up *S. barberi* as a new species. In the following key from Jeswiet's 1925 paper are given the characters on which the separation of the species is founded :

KEY TO THE SPECIES OF SACCHARUM

A. Main axis of inflorescence and cluster axes with long hairs. Glumes always 4. Lodicules either ciliate or not. If the spikelets of the same pair do not flower simultaneously, the pedicellate one always blooms first. Culms green, grayish green, greenish bronze, ivory or white.

1. Lodicules ciliate, long subterranean runners present, growing wild ....*Saccharum spontaneum*.
2. Lodicules not ciliate. Subterranean runners short.
   Sugar-producing, cultivated plants.
   a. Leaves broad (to 50 mm). Tall cane species, nodes all bobbin-shaped, greenish bronze (amongothers, Uba cane)...........*Saccharum sinense* Roxb.
   amend. Jeswiet.
   b. Leaves narrow, short inconspicuous cane species. Nodes usually cylindrical, grayish green, white, or ivory. Rather limited to India and Pakistan (among others, Chunnee cane).......*S. barberi* Jeswiet.

B. Main axis of the inflorescence never having long hairs, often glabrate; rachis modes glabrate or with very few hairs. Glumes generally 3, sometimes 4. Lodicules not ciliate. If the spikelets of the same pair bloom at different times, the sessile one always is the first. Culms differing in colour from pale or dark green to dark yellow, dark-red violet, often striped. Cultivated plant..*Saccharum officinarum*.

1. Fourth glume present. Vigorous plants with low sugar percentage.

Types: Among others, Fidji, Ardjoeno, Groen Duitsch New Guinea.

2. Fourth glume wanting. Plants generally with a high percentage of sugar.

Types: Among others, Cheribon, Batjan, Borneo, Bandjermasin, Preanger.

Jeswiet was no doubt aware that he was dealing with complex of facultatively and obligatorily asexual groups and he attempted to draw the natural species and race boundaries or artificial boundaries of the cultivated forms where most onvenient, using a minimum of diagnostic characters. He recognized that although the systematic treatment had to rest primarily on comparative morphology it was helpful to add a physiological character, synthesis and storage of sugar. His key recognizes close relationship of *S. sinense* and *S. barberi* and their joint relationship with the wild *S. spontaneum*. Phylogenetic relationship of *S. officinarum* with the other three species is indicated as somewhat more remote. Separation of *S. officinarum* into groups is recognized. After nearly 30 years there has been no revision of the genus but considerably more evidence of relationships has accumulated not the least of which was the not unexpected discovery in New Guinea by Jeswiet himself of the large feral cane species *S. robustum*, the closest wild relative of *S. officinarum* (13).

Theoretically *S. robustum* as the direct or cognate sexual ancestor of *S. officinarum* provides a means of approaching more closely the ideal selection of key characters for use in identifying and separating naturally or artificially its direct or hybrid derivatives. These derivatives include all the groups of cultivated forms. It is assumed here that *S. robustum* is involved in a principal role in the ancestry of all economic sugarcane. As in the case of *S. robustum* the same opportunity exists for selection and use of key characters of other putative ancestors of *S. officinarum* among them *Erianthus maximus*. A penetrating analysis of the roles of *S. robustum* and *E. maximus* in development of the noble cane complex is provided by Grassl (27), who described in detail the morphology of *S. robustum* and deposited type specimens in the U. S. National Herbarium.

He suggests on the basis of morphological, geographical and cytological evidence that noble sugarcanes are most closely related to these two species. A key character found by Grassl in certain segments of the noble sugarcane group, awned third glume, traces back to *E. maximus*. The secondary importance of *E. maximus* as a component of the noble group, in the inclusive sense, is recognized by Grassl. The noble sugarcanes are readily distinguished from the small wild cane *S. spontaneum* on the basis of taxonomic characters of the inflorescence and, although they can be made to hybridise, relationship is distant. Dr. Jesweit believed that certain off-type noble canes like Loethers evidenced some small admixture of *S. spontaneum*, partly on morphological grounds and partly because of the resistance of Loethers to sereh. Similarly, the susceptibility of Loethers and a few other off-type clones to the fungus parasite *Ustilgo scitaminea* Syd., the cause of smut in *S. spontaneum*, might be due to limited introgressive hybridisation involving *spontaneum*.

Summarizing the observations on speciation of *Saccharum* and the relative position of *S. officinarum* in the genus it seems clear that separation of all variants in terms of definitive species names is beset with difficulties and is particularly misleading in the case of the cultivated forms. A more factual systematic treatment would be to exclude from the genus as species all but *S. spontaneum* and *S. robustum* and recognise the other variants as horticultural species divided into two classes if necessary in future to distinguish between those derived by mutation and selection from a single ancestral sexual form and those derived from two or more such ancestral forms.

Until such drastic revision is made by competent authorities the needs of classification and convenience are reasonably well met by Dr. Jeswiet's classification, amended by the addition of *S. robustum* and *S. edule* Hassk, as follows:

REVISION OF PART "B" KEY TO THE SPECIES OF SACCHARUM

B. Main axis of the inflorescence never having long hairs, often glabrate; rachis nodes glabrate or with very few hairs. Glumes generally 3, sometimes 4. Lodicules not ciliate. If the spikelets of the same pair bloom at different times, the sessile one always is the first. Culms differing in colour from pale or dark green to dark yellow, dark red, violet.

1. Wild plants up to 10 m. tall, culms with relatively high fibre and low sucrose content, generally riverbank perennials. . . . *Saccharum robustum.*
2. Cultivated plants.
    a. Inflorescences aborted, leaves more or less pubescent ...... *Saccharum edule.*
    b. Inflorescences normal, culms with relatively low fibre and high sucrose content......*Saccharum officinarum.*

This minor revision is provisional and is proposed to correct the omission of *S. robustum* and *S. edule* pending more formal revision when the essential morphological and cytogenetic evidence is at hand. The deficiencies of this combination of naturally and arbitrarily drawn species boundaries do not defeat or even seriously impair the convenience and practical usefulness of the systematic arrangement. Only the intergrades will present difficulties. An experienced observer can with fair assurance say that a given specimen falls into one of the six species. No doubt the homogeneity of individuals in groups *sinense* and *barberi* resulted from sexual isolation somewhat different from the spatial, insular type mentioned as explaining homogeneity in the New Caledonian and Hawaiian noble groups but basically the principles are the same. Relatively few noble canes found their way from the primary centre of origin and diversity south of the equator to the shifting centre in India where they were modified by hybridisation with *spontaneum* forms and subsequently were extended northward. In northern India, which became by far the largest sugar producing area, flowering was suppressed. Even in the absence of inflorescence the majority of individuals can be identified to the species or group.

Mention was made of the possibility that the assumed genetic history of some of the groups may explain the existence of certain functional as well as morphological characters of individuals in each of these groups. Conversely, these characters, little used in taxonomy, might be useful in suggesting the relationships and derivation of groups. It is known that all hereditary characters in sugarcane are the expression of self-reproducing particles called genes derived from their ancestors. The characters in question are of different sorts; some of them are gross morphological characters, some anatomical, some physiological and some not measurable except in terms of visible or detectable reactions of the sugarcane plant. In the last mentioned category are reactions to disease organisms, cold, photoperiod, etc , all conceded to be derived from parental stock. The numbers and structures of the chromosomes themselves may, of course, be considered taxonomic characters.

The use of these characters, or some of them, is not new. According to the South African botanist, de Wet (23) "very early in the history of the taxonomy of grasses some investigators realized that the fundamentally important question of phylogenetic relationships may not be answered by a study of gross morphology alone. Duval-Jouve (1875) and Pee-Laby (1898) studied the leaf anatomy of different grass genera and came to the conclusion that anatomical characters might be used taxonomically. Additional evidence was presented by Hartz (1880) from a study of the types of starch grains in the Gramineae, and also by Grob (1896) from an examination of the histology of the epidermal surfaces of the leaves."

In more recent times these aids and additional ones have been used successfully as adjuncts to conventional comparative morphology in sugarcane taxonomy. Until more is learned about the genetic history of the different cane groups and until agreement can be reached as to what constitutes a sugarcane species, they will continue to be a main reliance as useful adjuncts to classification. Examples of these unconventional taxonomic and physiologic characters will illustrate their usefulness.

EXAMPLES OF USEFUL SUPPLEMENTAL CHARACTERS

Kinds and amounts of carbohydrates synthesized and stored in sugarcane, particularly sucrose and starch, corroborate to a surprising degree the boundaries of species and racial groups based on taxonomic characters. It is realized, of course, that selection by man rather than natural selection accounts for high sugar percentage in the cultivated forms and therefore the significance of this character phylogenetically should not be overemphasized. Percentage of sugar however, was found convenient and useful by Jeswiet in separating groups of *S. officinarum.* The starch percentage on the other hand is not only useful but, as the amount of starch was a secondary consideration in selection by primitive man, it is much more significant than sugar in suggesting phylogenetic relationships. A recent paper by Dutt and Narasimhan (24) reports on the progressive accumulation of starch in different stem parts of 215 wild, and cultivated varieties. Results showed practically no starch, or traces only, in

S. robustum and the 78 tested varieties of *S. officinarum*. The 26 varieties of *S. spontaneum*, 25 of *S. sinense*, and 85 of *S. barberi* showed fair to large accumulations of starch but the quantity appeared to be somewhat less in *S. sinense* than in *S. barberi*. *S. sinense* and *S. barberi* are believed by Parthasarathy (33) to have arisen in tropical India by promiscuous hybridisation of *S. officinarum* x *S. spontaneum*. It seems probable that *S. spontaneum* may have imparted this character to the hybrid offspring. Under "Origin and Dispersal" the theory of Parthasarathy and the slight difference between *sinense* and *barberi* in percentage of starch again will be referred to.

On the basis of comparative morphology and using vegetative characters only, Barber (8) classified a large segment of the Northern Indian cultivated canes in 5 groups, Sunabile, Mungo, Nagori, Saretha and Pansahi. In Jeswiet's revision of *Saccharum* he singles out as *S. sinense* the members of the Pansahi group and lumps the others as *S. barberi*, named after Barber. Ample testimony of Barber's discernment and good judgment is afforded by the cytological studies of Bremer (19) which essentially corroborated the validity of Barber's groups. With a few exceptions the individual clones of each group were found to have diploid chromosome numbers in common. The chromosome number *per se* is not a taxonomic character but in the circumstances described its corroborative value is impressive. Bremer raised the question of what proportion of the total number of Northern Indian cultivated canes was actually studied and classified by Barber, having in mind no doubt the possibility of "unclassifiable" intergrades.

Parenthetically, Bremer objects with some justification to the lumping of four of Barber's separable groups into one species, *S. barberi*, but his suggestion that this name be given only to the forms of one group, Saretha, seems even less desirable. None of these groups form a species by any presently acceptable rule. It is believed that ultimately they will be classified in aggregations of lower than species rank. Under the circumstances the shuffling of species names now applied to horticultural groups seems premature or immaterial. The significant fact is that the validity of Barber's classification of an array of subtropical sugarcanes, now believed to be species hybrids, was corroborated in a large measure by the testimony of Bremer's chromosome counts.

In a comparatively recent publication, 1915, C. A. Barber (8) stated that all previous classifications of sugarcane known to him made use of stem colour for separation of canes into the "main divisions". He pointed out that reliance upon colour for primary separation of groups was unsatisfactory "but colour is, none the less, an important character and canes assume quite definite tints which are of use in rapidly separating them at the mill. Colour is therefore always carefully noted." Barber's comment on previous unconventional and amateurish classifications overlooked some fragments of conventional taxonomic contributions long available in the literature and well summarized by W. Kruger in his book "Das Zuckerrohr" in 1899. Barber's observation directed attention to the convenience of stem colour as a useful supplemental character in distinguishing individual varieties or clones. It is significant that his experience was limited essentially to the cultivated canes of northern India in which stem colour is relatively inconspicuous. With the gradual accumulation of a broader knowledge of sugarcane phylogeny we may resurrect stem colour as an adjunct to morphology in providing evidence of lines of descent. In other words, a broad separation of the main divisions, or species and groups, can be supported by stem colour. Reference has been made herein to the wide range of striking, flamboyant colours of *S. officinarum*, the tropical garden canes of New Guinea and adjacent islands of Melanesia and their derivatives elsewhere. The wild ancestral species, *S. robustum*, includes forms with identical pigments and the same wide range ot conspicuous stem colours, green, yellow, brown, red and deep purple found in *S. officinarum*. In great contrast, the forms of *S. spontaneum* have green stems except for irregular reddish blotches which appear on stems of some forms with exposure to sunlight. Stems of the slender domesticated sugarcanes of northern India studied by Barber, provisionally retained as *S. sinense* and *S. barberi*, are either green or faintly tinted with the same colours found in *S. officinarum* and *S. robustum* but in comparison with them are rather drab in colour. With a few possible exceptions in the primitive Saretha group these northern Indian cultivated forms are considered to be hybrids between *S. officinarum* and *S. spontaneum*. The intermediate stem colours do not conflict with the idea of promiscuous natural hybridisation of *officinarum* and *spontaneum* announced by Parthasarathy (33).

The colour of the stem, or culm, is a useful adjunct to morphological characteristics in the identification of individual sugarcane clones but colour must be used with understanding of its limitations. The striking range of colours in the domesticated sugarcane clones described in this paper, *S. officinarum*, represents different combinations and concentrations of two series of pigments, the chlorophylls and the anthocyanins, and to a lesser extent the carotenoids and xanthophylls. Even in *S. officinarum* forms colour is subject to various internal and external influences and is only relatively constant. Recognition of causes of colour variation found in different specimens of the same clone and in different parts of the same stem is essential to practical utilization of the colour characteristic. Ultimate causes of the variations have not been adequately studied but the observed variations may be classified. They are mainly of four sorts. Those correlated with age of internodes, i.e. juvenile vs. mature internodes; those correlated with environment, i.e. exposed to sunlight or protected by leaf sheaths or otherwise in shade (and possibly influenced by nutrition or other environmental factors); those correlated with inner morphology which dictates the variable width of stripes; and, finally, those correlated with somatic aberrations or mutations, the often observed but little understood colour sports or variants. In observing colour variants in a large collection for many years one is impressed by the evidence that some clones are prone to vary and also to revert in a typical manner, i.e., to produce wholly green or wholly red sports from a green-red striped form and then revert to the striped form with no apparent change in the original combination and concentration of basic pigments.

As judged by Finlay colour photographs made thirty years ago the great majority of clones remain as they were when collected, with no colour variation except the mentioned progressive colour changes in juvenile to mature internodes, the transitory changes caused by environmental factors and the variable width of stripes in the ribbon canes. For these reasons the stem colour, when used judiciously, is an aid in distinguishing between forms of *S. officinarum.* The large sooty patches frequently seen on the stem epidermis of sugarcane near the point of attachment of leaf sheaths are the dense, thin stromata of sooty mould, a black non-parasitic fungus which feeds on sugary exudates of the cane or on the honey dew excreted by sucking insects like mealy bugs.

Abscission of the leaf sheaths and attached blades is another useful supplemental character which distinguishes the species and racial groups of *Saccharum.* Most *S. officinarum* forms readily shed their leaves progressively from the base upward during normal growth and this phenomenon is characteristic of the majority of *S. robustum* forms suggesting a closer relationship of *officinarum* with *robustum* than with *spontaneum*, the forms of which usually have clinging leaf sheaths.

If every part of all original sugarcanes in the world, both domesticated and wild, could be made to disappear by some magic, leaving visible only the fungus, bacterial and virus parasites to present ghostly outlines of root, stem leaves, inflorescence and internal tissues, it would be possible to lump the unseen canes into groups approximately as they are now classified according to conventional taxonomic characteristics. This is owing to the high degree of biological specialization in some cane parasites which makes obligatory their association with certain kinds of sugarcane. Such discriminating selectivity is not characteristic of all cane parasites but the phenomenon is common. For various reasons other kinds of cane are uncongenial to the same parasites hence they are called resistant or immune.

It happens that the uncongeniality or resistance is heritable and at least some offspring are endowed with it. Controlled inheritance of disease resistance in sugarcane was first demonstrated in 1897 by J. D. Kobus who crossed the susceptible noble cane Black Cheribon with sereh-resistant Chunnee in Java and obtained a progeny with some resistant and economically useful individuals. In the preparation for that work the assembling of great numbers of cane varieties from many countries for resitance tests was indiscriminate as to species and racial groups partly because the classification of *Saccharum* forms was little known. Moreover, because sereh was known only in Java, varieties gathered elsewhere for test had to be selected more or less at random.

The conception of *racial* susceptibility or resistance to disease in sugarcane was a gradual development, obscured very often by limited evidence and limited vision. Modern technical literature on sugarcane is still cluttered with observations that the tropical noble canes are "susceptible to disease" and that, for example, *S. spontaneum* is "disease resistant." These offhand references many times are generalizations and do not specify which one of the hundred or more cane diseases, if any, is in the mind of the observer.

Not until the world-wide spread of mosaic in the decade 1915-1925 directed careful attention to innumerable varieties of all types of cane did the idea of sugarcane racial reaction to disease crystalise and emerge as one of the practically useful tools in cane breeding (10, 12). The rare occurrence of natural mass exposure of sugarcane to a particular disease agency and the plant quarantine deterrents and other difficulties standing in the way of controlled mass exposure to diseases still remain as obstacles retarding the accumulation of desired precise knowledge. Enough is known, however, to provide significant examples of obligate selectivity in the consorting of particular cane races and disease agencies. The illustration will be limited to two major diseases.

1. All forms of *S. robustum* tested for reaction to the virus of mosaic were found readily susceptible with evidence of deleterious effects, and all forms of its derivative *S. officinarum*, so far as they have been tested or observed are also susceptible and as a rule are much injured; an added confirmation of close relationship between *robustum* and *officinarum*. In contrast, the forms of *S. spontaneum* are immune to mosaic or at least are so highly resistant that detection of the disease by outward signs is not possible with certainty; and indication of remote relationship with *officinarum* (1)

The hybrid race *sinense* (*officinarum* × *spontaneum* if we follow Parthasarathy) is susceptible but all forms are extremely tolerant of the effects of infection. Similarly, the *officinarum* × *spontaneum* race *barberi* is also susceptible and, moreover, so far as observation has been possible, its members show readily detectable outward signs and are somewhat more injured than those of *sinense*. This may be an indication of different clones of *officinarum* × *spontaneum* involved in the parentage of the two races, or possibly of the same combination in reciprocal crosses. The fact remains that in the two races is found a range of intermediates, between *officinarum* and *spontaneum* so far as susceptibility and extent of injury is concerned (2)

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(1) The occasional occurrence of pronounced symptoms in *Spontaneum* has been noted. In a selfed progeny of three hundred *S. spontaneum* Mandalay seedlings produced at the Palm Beach Research farm in 1952 five individuals became infected with mosaic and sharply conspicuous leak markings were observed. Parthasarathy's theory of promiscuous natural hybridisation, *officinarum* x *spontaneum*, could account for wild growing hybrid forms closely resembling *spontaneum* as readily as for selected domesticated forms with characters resembling *officinarum*.

(2) A puzzling attribute of sugarcane mosaic virus or of the defense mechanisms of grasses in general is the early discovery that although apparent immunity is found within the genus *Saccharum*, it has been demonstrated that certain grasses in *other* tribes can become infected transitorily by artificial inoculation or even by the natural insect vector if the grasses are growing in the vicinity of infected cane (11). There is no evidence that the disease persists for long in the grasses remotely related to sugarcane. Sugarcane itself is known to recover but the evidence is more convincing for varieties known to have some *spontaneum* genes (37)

2. *S. spontaneum* is very susceptible to attack by the pernicious fungus parasite *Ustilago scitaminea* which causes the disease "smut", so named because it transforms the growing point of the stems or floral initials into a sooty, whip-like appendage emerging from the top of the plant. On *spontaneum*, smut is known in India, Turkestan, Indonesia, and the Philippines and probably is present but unrecorded in other oriental countries.

The *S. officinarum* varieties are singularly free from attack by *U. scitaminea* although it has been reported sporadically and at long intervals on a few of them like Loethers in Java, "Luzon White" in the Philippines and perhaps a few others. These are "off-type" *officinarum* possibly with a limited admixture of *spontaneum*. The situation as regards susceptibility and resistance to smut is seen to be the reverse of that just described for mosaic, in which *officinarum* is susceptible and *spontaneum* resistant. The hybrid races *sinense* and *barberi*, *officinarum* x *spontaneum*, are notoriously susceptible to smut in India where it has long been regarded as a major disease. The improved Co. varieties which are recent combinations of *officinarum* and *spontaneum* are carefully tested for reaction to smut before they are released for cultivation. The majority of seedlings are discarded. Fortunately, owing to this screening process, some of the survivors are listed as tolerant, or even resistant, but most of them are susceptible. In this reversal of character where *officinarum* plays the part of the parent endowing resistance to its off-spring and, on the other hand, *spontaneum* is the one conferring susceptibility we see some curious and significant implications. Up to the time of the mosaic epiphytotic the commercial sugar industries of the New World were based exclusively on *S. officinarum* and smut was a thing unknown.

Now the same industries are firmly based on hybrid varieties with an admixture of *spontaneum* for protection against mosaic, but vulnerable to smut. The inevitable pursuit, and overtaking, of the host by the highly specialized parasite has now happened. How it arrived is not known but for the first time in history smut was recently reported in northern Agrentina and rapidly moved into south-eastern Brazil. The presence of *Saccharum spontaneum* even though somewhat diluted in the commercial canes of the Americas could make itself known sans host plants by the ghostly outline formed by the parasite.

GEOGRAPHIC ORIGIN AND DISPERSAL

In foregoing sections we have endeavoured to define the complex group of original noble sugarcanes and to describe their economically useful qualities which have made them indispensable in the evolution of all cultivated sugarcane. Of equal importance in a practical sense, which will be developed hereunder, is the geographic centre of origin and dispersal which necessarily involves the genetic origin of these forms.

Origin.—In a recent book dedicated to N. I. Vavilov, Darlington (21), under the heading "The Origin of Cultivated Plants" says : "A description in terms of formal species names and a single process is likewise misleading as applied to the origin of the sugarcane. Here we are concerned with a complex of wild forms of *Saccharum* with chromosome numbers between 48 and 112, classified under the names *spontaneum* and *robustum* and distributed between Turkestan and Polynesia These forms, by selection for size and sugar content, and of course increase of chromosome number, have given rise to the cultivated species called *barberi* in India, *sinensis* in China, and *officinarum* in Java and the Pacific. In recent years these have all been crossed together and with the wild forms and, with further increase in chromosome number, have finally given us the prodigies of Passeroen and Coimbatore."

Although one may agree with the first sentence, the statement is otherwise so diffuse that it is likewise misleading and might better have been omitted. A discriminating review and selection from the literature, particularly since 1928, would have made possible an unambiguous concise statement in less words, e. g. one wild *Saccharum* species localized in New Guinea, *robustum*, gave rise by the occurrence of polyploidy and selection to a group of tropical cultivated canes, *S. officinarum*, and, as a much later second step, migrating forms of *S. officinarum* in south-eastern Asia hybridised with forms of the widely distributed wild *S. spontaneum* and gave rise to several groups of thin subtropical cultivated canes, among them *sinense* and *barberi*, (Figs. 1, 2, 3, 4).

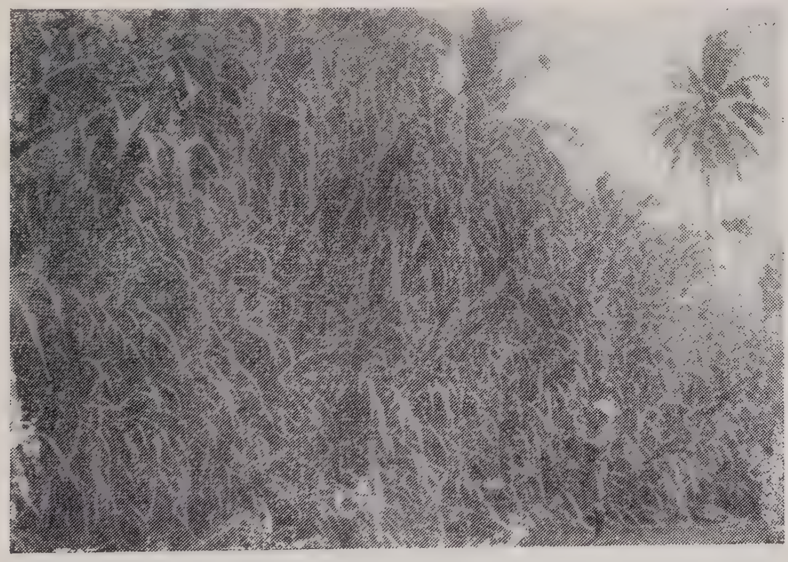

Fig. 1. *Saccharum robustum* 28 NG 251, the type of the species in the locality, left bank of Laloki River 18 miles from Port Moresby, Territory of Papua. This relatively broad-leaved, thick-stemmed clone is greenish yellow when young, becoming bright yellow. It has been distributed by the U.S.D.A. to numerous institutions in tropical and sub-tropical countries and has proved reasonably adaptable. The creeping, flexuous stolons (up to 60 feet in length in the natural habitat) do not develop when it is cultivated in well-drained situations. This is true even in New Guinea where the plant has been transported by man to well-drained, upland situations.

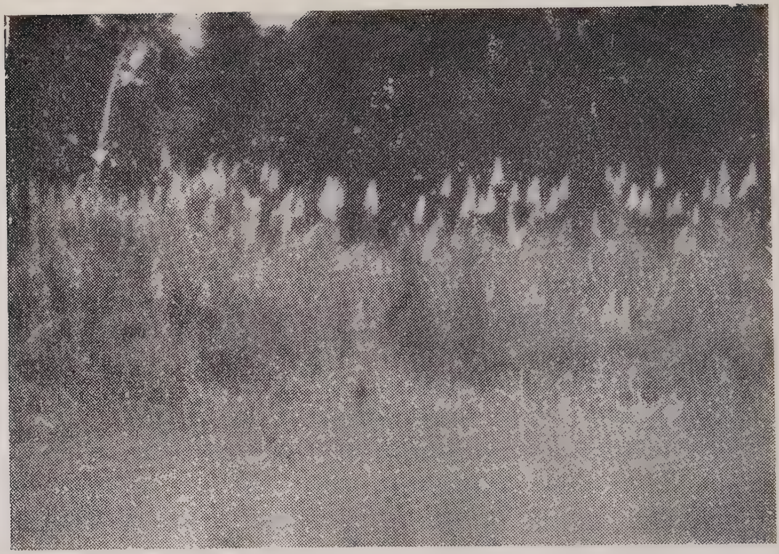

Fig. 2. *Saccharum robustum* forma *sanguineum* 28 NG 219. Left bank of the Sepik River about 450 miles by river from the sea. The frequent, intermittant flooding of *S. robustum* in its natural habitat is well illustrated in figures 1 and 2. This form is bright purplish red with bright red flesh except at the centre of the solid culms. The internodes are relatively long in the natural habitat, shorter when displaced to well drained situations.

Compared with nature's evolutionary role and the achievements of untutored or at least unlettered and forgotten men who selected *officinarum* the reference to modern cane varieties bred at modern experiment stations as "prodigies" is overdrawn. For adaptability and yield in tropical countries the long-term record of the old Cristilina and Cheribon canes stand comparison with modern hybrid varieties very well. Much to their credit cane breeders have made recent dramatic advances in correcting environmental misfits, for example in southern, subtropical United States through research conducted by the U.S. Department of Agriculture. The tropical *S. officinarum* forms cultivated there for more than a century were out of their element. They were replaced with a distinctly different type of sugar-bearing plant, namely the species hybrids *officinarum* x *spontaneum*, bred in Florida beginning in 1919 and much better adapted to the rigorous climate (10, 12, 14). Also to their great credit, as current production statistics verify, sugarcane breeders in Hawaii, Barbados, India, Australia, Mauritius and U.S.A. have a little more than held the line against the challenge of disease and other adversities. Without exception every significant advance in cane improvement, including the doubling of chromosomes of the valuable *officinarum* gamete, has been patterned after the guiding inscriptions of nature in the area of origin. Some of these guides like the natural species hybrid Kassoer were brilliantly interpreted (18). It is a worthwhile privilege for an observer to traverse that area and try to interpret the inscriptions, however time-ravaged some of the tablets may be.

The origin of the sugarcane is not as cryptic as the origin of many other cultivated plants in which ancestral forms are wanting and resort therefore is necessary to circumstantial evidence, questionable human records or the testimony of palaeontology. The basic wild forms of sugarcane or their recognizable

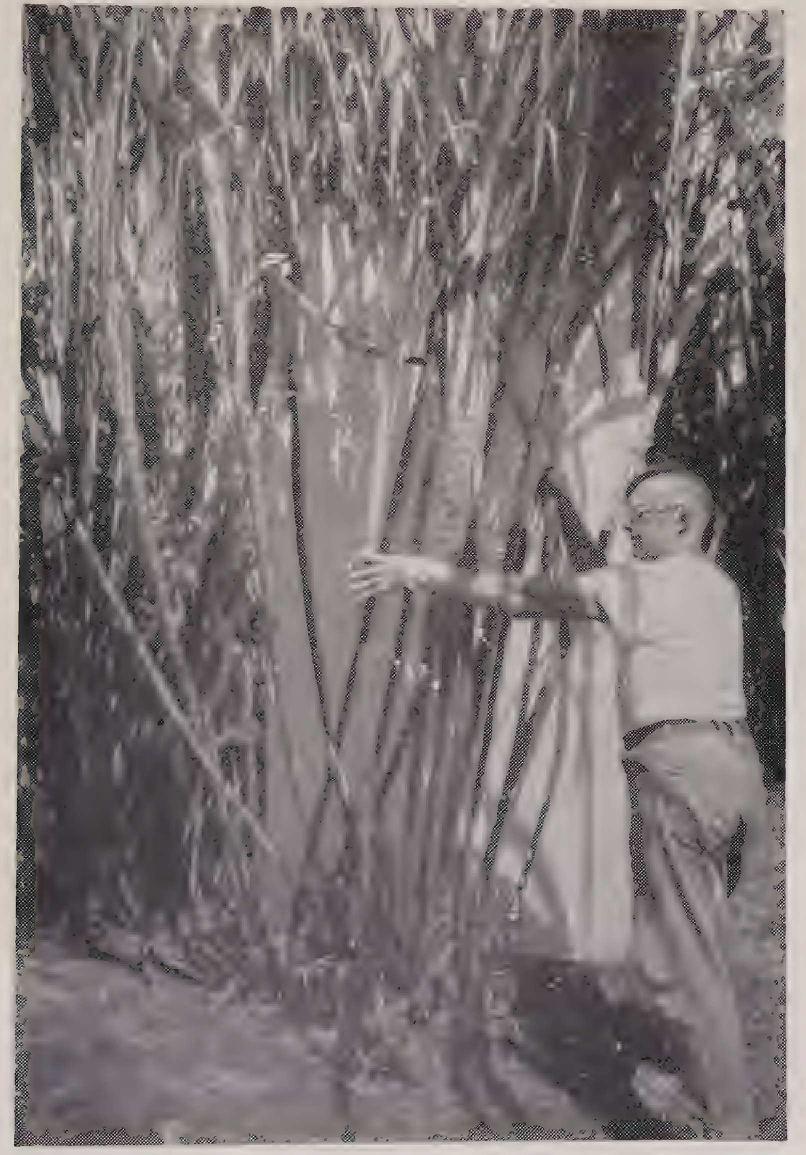

Fig. 3. *Saccharum robustum* forma *sanguineum*. A young stool of 28 NG 219 in well drained soil at Canal Point, Florida. Note the natural self-cleaning referred to in the text. This clone is extremely woody but strikingly resembles the garden canes in gross morphology.

polyploid cognates are extant and the morphological boundaries of the cultivated forms derived from them, thanks to a measure of biological isolation, are still fairly discernable.

It is still possible, and this is important, to reach back and recapture from the wild progenitors and original cultivated groups some genes useful in holding the line against adversities like diseases. This circumstance is the chief justification

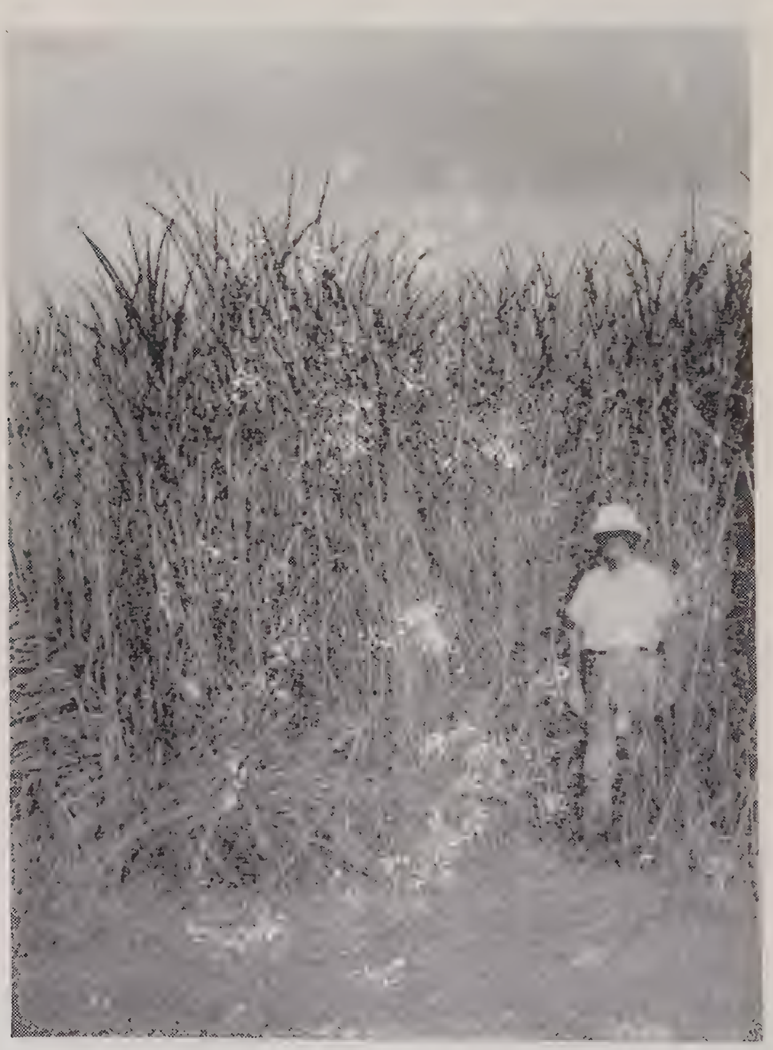

Fig. 4. *Saccharum spontaneum* 28 NG 292. Swamp near the type locality *S. robustum*. This thin-stemmed form is typical of the species *spontaneum* in New Guinea, and average in size for the species throughout its extensive range. A comparative study of Figs. 1, 2, 3 and 4 graphically supports the thesis of garden cane origin from *S. robustum* presented *in extenso* in this paper. (Photo by Jeswiet).

for the effort of collecting and maintaining for study generous samplings of the wild and early cultivated species of great groups of sugarcane. With them, and with them only, a cane breeder commands the full range of sugarcane diversity and potentialities. In starting a new line of breeding one can make a cross and predict with some degree of confidence that the F_1 progeny will include among the individuals a few with the desired basic quality, for example adaptability to given environmental factors, reasonably high sucrose percentage, low fibre percentage, resistance to one or another of the known disease organisms (which in themselves exchange genes and mutate), or other heritable qualities known by experience to reside in the particular group. If the confusion visualized by Darlington, or at least by the casual reader of his paragraph were literally true not much would be left of planned cane breeding except the use by a cane breeder of his favourite "proven parents" which in general are valuable only temporarily and usually for a particular producing area. A flareup of disease can force drastic changes in such breeding stocks of known constitution. Most proven parents represent only small arcs in the full circle of sugarcane diversity.

The centres of diversity of sugarcane may or may not be the geographic centre of origin. Fixing the authentic centre of origin depends on confirmatory evidence chiefly the coexistence in the area of proved or credible, putative ancestral forms as well as the complete *range* of diversity. With the domesticated sugarcane the evidence since 1928 (14) is exceptionally trustworthy in establishing New Guinea as the geographic centre of origin of the original noble canes and *S. robustum* variants as the sole or principal ancestral forms. Also, on good evidence several shifting or satellite centres of diversity, involving hybridisation of the migrants with other grasses, have been established, notably Polynesia (27) and northern India (33) and on collateral evidence numerous other satellite centres. In contrast with most ancient cultivated plants the singular advantage facilitating studies of sugarcane origin lies in the fact that at that centre organic evolution of the principal component of sugarcane continues to operate under natural conditions. Certainly persevering artificial selection and solicitous care by Neolithic horticulturists continue to operate much as undoubtedly they operated thousands or tens of thousands of years ago (13).

Varieties similar to those described in this publication continue to evolve there today by unceasing natural backcrossing of the selected forms with the wild *S. robustum*. As the closest wild relative of the noble sugarcanes, found exclusively in the area where numbers and diversity of noble canes are incomparably greatest, we take for granted the parental role of S. *robustum*. Irrespective of whether or not the diploid ancestor of *S. robustum* still exists the impact of that wild species, creating greater diversity, continues. The considerable number of obviously recent natural backcrosses found carefully tended in village gardens during 1928 testifies that the process of evolution and selection, however slow or in whatever direction, is unabated.

This helps to explain the far greater scope in diversity of the New Guinea original forms compared with the migrant forms carried in past millennia by man to the sites of potential satellite centres of diversity. These migrant forms had to be limited in numbers because of the great difficulties and hazards of travel. They and their descendents represent only selected small segments of boundless variants available at the primary centre[1].

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[1] A morphological study of vegetative characters of more than 300 garden canes by E. Artschwager and E. W. Brandes (in press) confirms that clones of the group from Hawaii are the most homogeneous, those from New Caledonia are less homogeneous and those from New Guinea are the most diversified in regard to the characters employed in the description and classification of the clones. All groups have representatives with hairy culms.

HAWAII.—Most outstanding character for the group is the long sloping transitional auricle. The auricles are heavily fringed with the fringe sometimes descending beyond the insertion point of the auricle ; the inner auricle has, in addition, a small calcarate hook. The ligules are tall or medium tall and inconspicuously fringed (hair group 61). Culms only slightly waxy ; but furrows as a rule prominent ; flesh soft and of an orange hue. The buds are usually large and hairy with hair group 24 diagnostic of the Hawaiian Originals. Leaf sheath and upper sheath margin may be smooth or hairy. The midrib is smooth, sparsely pubescent and occasionally hairy. Dewlaps ascending ligulate and sparsely pubescent. Stem epidermal pattern No. 2 prevalent.

NEW CALEDONIA

This group is sharply subdivided into clones with a prominent ligular fringe (group 61) and clones with an inconspicuous group 61 ; the ligule itself is tall or medium tall—rarely narrow. The culms are slightly waxy and only half of them have a prominent bud furrow. Root bands are more or less narrow and rows of root primordia few. The leaf sheaths are usually hairy but the fringe on the upper sheath margin (group 56) is seldom present. Bud pubescence often prominent and dewlap hairs (52 and 58) often dense and semilong. The midrib, behind the ligule, is slightly or prominently hairy on one half of the clones.

NEW GUINEA

In contrast to the Hawaiian and New Caledonian canes, the New Guinea group contains a large number of clones with prominent lanceolate auricles and narrow ligules. One half of the clones have prominent bud furrows and hairy buds. Among the latter is a subgroup with secondary wing development of the prophyll. Although only one third of the clones have smooth sheath, prominent sheath pubescence is found in only 9 percent of the clones. In about three fourths of the clones the midrib is smooth. Prominent midrib pubescence is rare and a prominent ligular fringe (group 61) is limited to 2·6% of the clones. The upper sheath margin is fringed in one third of the clones but the fringe is prominent in only 5·8% of the canes in this group. All characters show a greater range of diversity than do those of the other two groups.

OTHER

In contrast with New Guinea the trend towards homogeneity is detectable among the forms in other secondary centres of diversity with the outstanding exception of northern India where it is assumed that extensive hybridisation with forms of *S. spontaneum* took place.

There is some evidence that the initial migrant clones were prudently selected from the higher levels of quality as chewing canes. On the average they are softer and higher in sucrose percentage. After they multiplied where conditions favoured seedling production in their new homes and were reselected the limited heterogeneity is evidenced by greater uniformity compared with the wider heterogeneity and diversity of the larger primary group in New Guinea. In Polynesia, for example, where land areas are small and close relatives of the migrant noble canes are scanty, the continued evolution of wide variants was suppressed. The same is true of New Caledonia. New Guinea on the other hand possesses the requirements of vast size, diverse climates and numerous inhabitants as well as the wild ancestral *Saccharum* and may be described as a proving ground for domesticated sugarcane where mutations in Mendelian populations had and perhaps still have full play. As we know, nature has not endowed its creations with a providential ability to produce only mutations beneficial to exploiters like man. Many chance seedlings are picked up by primitive man in New Guinea which after periods of trial in the gardens are found to be inferior and are discarded. Some of these inferior garden forms are in the reference collections.

DISPERSAL

The dispersal of *S. officinarum* forms from New Guinea and its eastern outlying islands began in prehistoric times and still continues. The evidence on early pathways of the migrants is clear enough and even the relative times of migrations radiating outward in several directions from the centre can be postulated with fair assurance. However, the absolute time when the movement outward started is more obscure. The most that can be said on present evidence is that initial migrations must have begun many thousands of years ago, long before the presence of man in Polynesia, and were, in order of time, south-eastward to the compactly grouped islands of Melanesia, westward to Indonesia and northwestward to continental Asia and the Philippines. Migrations eastward to the far flung islands of the "Polynesian Triangle" were comparatively recent, i.e., beginning not earlier than about 500 A.D. Obviously, in the absence of documentation, reliance must be placed mainly upon botanical evidence which is well supported, however, by ethnographical evidence. Legends, ancient history and philology are frail reeds upon which to reconstruct the place of origin and dispersal of an ancient cultivated plant like sugarcane.

There was no possibility of *S. officinarum* dispersal by natural means because of the character of the propagating material, stem cuttings, and also because of the indispensable need for weeding and care of the plants by man. Natural dispersal by seeds of the wild progenitor *S. robustum* was effectively limited by water barriers. There is some evidence, however, that typical *robustum* was carried as a minor economic plant by the Papuans to the smaller fringing islands of New Guinea and southeastward as far as the New Hebrides (16).

The durable stems are used today in constructing garden fences for protection against wallabies and pigs, roof parts of their amazingly large and elaborate houses and to some extent as shafts for assegai-like throwing spears. For arrow shafts the more slender stems of *Miscanthus* and *S. spontaneum* are preferred.

This reference to the warlike character and the material culture of the Melanesians, particularly the Papuans, is not a digression from the subject. Papuans are and presumably have been from time immemorial the traditional bitter enemies of their close neighbours to the west, the Indonesians. As late as 1860, according to Alfred Russell Wallace (38), the Indonesians had good reason to avoid the coast of New Guinea and its aggressive, untrustworthy inhabitants. The Papuans of many remote interior areas of New Guinea can be so described today. Although conceding that the Papuans are violent and cruel, Wallace rated them intellectually higher than the more civilized Indonesians. It is obvious that occasional contacts and in a small way even barter between these distinctly different races of people took place but always, as Wallace described it, on neutral ground such as the Aru Islands where the resident Papuans were less truculent than those of the main island. There is no reason to doubt that variations of the barter between sworn enemies may be very old. In 1928, in the upper reaches of the Kikori River, we encountered a curious "sight unseen" method of barter between hostile tribes of Papuans. The delta swamp dwellers carried conch shells up the river and left them on neutral ground for the hill tribe, returning later for products (which we were unable to identify) left by the hill people. Males of the hill tribe used the shells as a public apron, or sheath, supported from a rattan belt. Thus, in what was essentially a state of armed truce and through intermediaries some of the products of New Guinea, including sugarcane, were funnelled to Indonesia.

It is rather significant to note that in his long account of observations during six years of continuous travel from island to island of the Malay Archipelago the naturalist Wallace took no notice of sugarcane until his narrative reached the point of describing the Aru Islands off the south coast of New Guinea. There he was indeed impressed with the dietary importance of sugarcane as a direct consumptive product of the garden. In his words "the sugarcane was finer than any I had ever seen. The canes brought to the boat were often ten and even twelve feet long, and thick in proportion, with short joints throughout, swelling between the knots with the abundance of rich juice. At Dobbo (the trading village) they get a high price for it, one penny to three pence a stick, and there is an insatiable demand among the crews of the praus and the Baba fishermen. Here they (the Papuans) eat it continually. They half live on it, and sometimes feed their pigs with it. Near every house are great heaps of the refuse cane ; and large wicker-baskets to contain this refuse as it is produced from a regular part of the furniture of a house. Whatever time of the day you enter, you are sure to find three or four people with a yard of cane in one hand, a knife in the other, and a basket between their legs, hacking, paring, chewing, and basket-filling, with a persevering assiduity which reminds one of a hungry cow grazing, or of a caterpillar eating up a leaf."[1]

The story is quoted because I know of no better way to illustrate the difference in long established eating habits of Indonesians and Papuans and the incomparably greater importance and antiquity of sugarcane in the diet of the Papuans. For ages the Indonesians, like their relatives of Indo China and China, have been rice eaters. Some of them chew sugarcane occasionally as an esteemed confection. The carbohydrate food of Papuans for ages has been obtained from swamp sago palms (starch) and from taro, yams and sugarcane (starch and sugar) cultivated in rain forest clearings. The sugarcane is invariably present in the untold thousands of diminutive mixed gardens in the forests tended by the two million or more part-time gardeners constituting essentially the entire population of New Guinea and its outlier isles. How did they learn to eat cane ?

It has been said that in times of famine primitive man would eat bark, roots or anything he could chew and swallow. To a hungry hard-pressed Papuan of long ago discovery of even small amounts of sustaining sweet carbohydrate food within the hickory-hard rind of wild *S. robustum* stems would send him searching for other and possibly softer specimens. In my own experiments on the practicability of chewing and taste-testing *robustum* clones I discovered much variation in hardness and sweetness. Some, however, including the very hard red-fleshed *S. robustum sanguineum*, were highly unmanageable.[2]

According to our explorations and studies of sugarcane collected in the area of origin and early dispersal, it cannot fail to impress one as significant that the hard wild canes of *robustum* type have been found together with the soft garden canes along only one pathway of migration. This is the arc of densely distributed islands extending southeastward from the Bismarck Archipelago to the New Hebrides, thence eastward over a longer stretch of water to the Fiji Islands. Up to the present time feral, *robustum* type sugarcane has not been reported elsewhere. On this evidence we postulate that the first migrant sugarcane transported from New Guinea followed this pathway. Corroborative evidence is found in the fact that this area almost precisely marks the range of the Papuasians, or Melanesians. Anthropologists have evidence

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1. Mr. Wallace's account of cane-chewing by man and beast 100 years ago is no doubt unintentionally exaggerated and due to his understandably limited observation of Papuans on the New Guinea mainland Although I have seen a young pig being suckled by a Papuan woman, the grown pigs, according to my own observations, ordinarily are denied the fresh unchewed cane. They must make shift with the expectorated frass or "chewings". The gardens are carefully barricaded against both tame and wild pigs.

2. Only two or three decades ago most sugar technologists had little conception of the large numbers and great range in forms of *S. spontaneum*. Probably because most cane variety collections have limited specimens of *S. robustum* today the same restricted conception of its diversity prevails.

that Melanesians also reached North Island of New Zealand before the Polynesian migrations to New Zealand, but because of climatic limitations sugarcane was not important there.

In connection with the first cane migration mention should be made also of another hard-stemmed sugarcane type domesticated and used extensively by the Papuasians which, according to the evidence of its vegetative characteristics doubtless was selected from *S. robustum*. This is the odd *S. edule* with abortive, cauliflowerlike panicles extensively used as food along the first track of migration. Clones of *S. edule*, being completely sterile, survive only under domestication and the processes of evolution are effectively arrested. These peculiar garden forms may therefore be very old and could have arisen from *robustum* earlier than the soft-stemmed chewing canes. Together with the latter cultigen specimens of *S. edule* are found on the Indonesian islands west of New Guinea, probably the second pathway of migration.

The second pathway of migration and by all odds the most important was westward to islands of Indonesia, Philippines, the Malay Peninsula, Indo China and the arc around the Bay of Bengal. The importance of that migration lies in the fact that it laid the foundation, long afterward in tropical India, for exploitation of sugrarcane as raw material in the manufacture of sugar. This marked the transition of sugarcane cultivation from a horticultural routine to a field crop operation.

The discovery of practical sugar making methods ushered in the period during which first mentions of sugar and sugarcane were made in recorded history. In his painstaking bibliographic research (22) Noel Deerr makes the assumption quite logically that the knowledge of sugarcane and sugar displayed in the Indian literature of two or three centuries on both sides of the beginning of the Christian era, and the reference to sugar by soldiers of Alexander the Great returning from western India (325 B.C.), point to the presence there of the sugarcane for a period long prior to the time of these earliest records. In our problem of paths of migration and shifting centres of diversity of *S. officinarum* it is necessary still to rely on the botanical evidence but these early records, both Indian and Chinese, are useful in several details beyond merely establishing more accurately the time and place of migrations.

The reference to soft and "thick" canes (and thus inferentially to hard and thin ones) and to peeling and chewing sugarcane as a confection suggests that only our migrant noble cane could have been meant. The noble canes do not grow normally and produce flowers in India above the tropic. For an explanation of the presence of the relatively thinner and harder sugarcanes *S. sinense* and *S. barberi* in subtropical northern India and corresponding parts of China it is necessary to return to the safer ground of botanical evidence.

For many years Barber (8) believed the slender cultivated canes of northern India to have been derived from the indigenous *S. spontaneum* but he found some similarities between these cultivated canes and the tropical noble canes which led him to suggest that both types may have had a common origin in *S. spontaneum*. Parenthetically, before the discovery in 1928 of *S. robustum* in New Guinea, this belief was held generally but vaguely by botanists. In 1920 Barber (9) was driven to conclude that the tropical noble canes must have had a separate origin in some different species "now lost in the wild state". He did not attempt to reconcile the anomaly of intermediate *S. spontaneum* and tropical noble cane pulvinar and rhizome characteristics that he had noted previously in the northern Indian cultivated sugarcanes.

It was left for Parthasarathy in the light of cytological and taxonomic evidence accumulated since 1920 and the concept of tropical noble cane origin since 1928 to construct an ingenious and acceptable explanation of subtropical Indian cane origin, namely the promiscuous natural hybridisation of tropical noble (*S. officinarum*) forms and indigenous subtropical *S. spontaneum* forms south of the tropic (33). In the selective processes by early agriculturists the hybrids were singled out as better suited to the rigorous climatic conditions northward and became predominant there. In a later brief publication on the origin of *S. officinarum*, not cited, Parthasarathy adduced cytological evidence to show that *S. officinarum* may have a basic complement of genes in common with other fairly close relatives of the Andropogoneae widely distributed in India. This relationship is obviously quite possible and readily can be reconciled with our theory of *S. officinarum* origin from S. *robustum*. The obvious purport of the brief paper, however, i.e., that *S. officinarum* may have originated in India, is not well supported by such evidence.

Although *S. spontaneum* is found in the islands of Melanesia and Indonesia no corresponding need for climatic adaptation had to be met by early horticulturists and the small wild cane played a minor role, if any, in the final steps of development of the tropical noble garden cane.

The documented history of sugarcane in northern India together with reasonable inferences on the lapse of time between arrival of the migrant garden cane and the dates of first documentation in India takes us back about 3,000 years. Considering the perishable nature of the sugarcane propagating material and the hazards of transporting it long ago it is not unreasonable to allow an equivalent span of years for the slow and interrupted journey from Papuan gardens to Bengal and Indo China. It is true that the relatively short distances between the islands ranging westward and northwestward from the island of New Guinea and the favourable climatic conditions did not impose a single effective barrier but barriers imposed by man were formidable.

Even in the Mediterranean countries of those days the lonely stranger was rare, suspect and endangered. In New Guinea one may observe today among Neolithic age men in the still uncontrolled parts of the deep interior a projection back to prehistoric conditions that probably existed on the track of sugarcane migration 6,000 years ago. If for any reason a man takes a walk beyond the pale of his tribal community he risks his life and therefore he carries very little except his weapons, his betel nut chewing equipment and his fire-making apparatus conveniently worn as a belt. He is alert, stealthy and constantly poised for flight. It cannot be assumed that much of the early dispersal of cane was accomplished by individuals going about in that manner. Small mass movements of men to nearby new territory, as when population pressure and the food quest or intra tribal disagreement force the setting up of a daughter village is a more probable method. Quite obviously the establishing of outpost villages by primitive men would involve extension of their material culture including domesticated plants. Except under occasional extraordinary circumstances which would force involuntary small mass movements of men by water the encroachment of sugarcane into new territory must have been as slow, but in the fullness of time as inexorable as the flow of cooling lava. If we allow three thousand generations of cane, propagated annually by cuttings, for the measure of time on the second track of migration it is probably an underestimate. Since conditions at many places along the track were favourable as potential centres of diversity and reselection, it is not to be wondered that *only a few* of the clones in the present study listed as "miscellaneous nobles", i.e., scattered nobles obtained from various institutions with no authentic information on place of origin, are indentical with existing New Guinea nobles. The wonder is that a fair number of them actually are indentical with or barely distinguishable from clones recently found in New Guinea.

Regarding types of curiosities or oddities among the whole gamut of noble canes it is significant that not a single oddity collected or reported from principal satellite centres of diversity like Indonesia, Malay Peninsula, Indo China, New Caledonia and Hawaii is missing from the aggregation of highly diversified forms collected in New Guinea. These oddities include the striking purple-leaved form sometimes used as an ornamental, the "rat" cane with a felt of hairs on the stem resembling fur, the "Suede glove" canes with dull, chamois-like stem epidermis, the gigas type called elephant cane and the "egg" cane with zig-zag ovoid internodes. In addition there is the primitive "fish roe" cane with cauliflowerlike abortive inflorescence previously mentioned as probably an earlier mutation from *robustum.*

By no stretch of available botanical evidence or of human credulity is it possible to make the assumption that these varied forms of conventional nobles and the botanical "jokes" flowed inward to a vortex or were drawn from all quarters as by a magnet, to New Guinea. That would be against all probability in the statistical sense and irrational in plain horse sense...something like carrying coals to Newcastle.

On the basis of all combined evidence we are led to believe that sugarcanes ; i.e., the domesticated noble canes, had their origin in New Guinea and by successive impacts radiated outward. This pyramiding of evidence on origin and dispersal of the sugarcane may seem to be pressing the point unnecessarily. However, since every work of reference and the introduction of every book on sugar prominently displays misinformation or a hedging vagueness on the subject, it seems appropriate to present what first hand evidence we have assembled in a long experience covering all areas mentioned supplemented by such interpretations as seem valid.

The last of the classic trails of migration of the noble garden canes was blazed by those incomparable mariners the Polynesians. There is no botanical evidence in the nature of indigenous wild *Saccharum* forms in the flora of the Polynesian islands that could support the view, formerly held by a number of botanists, that garden chewing canes originated in those islands. These loosely verified opinions were held before the discovery of *S. robustum* in New Guinea. Good evidence has been presented by Grassl supporting the theory that the Hawaiian original sugarcanes, or some of them, represent segregates resulting from natural crosses of the imported Melanesian garden and *Erianthus maximus*, which is indigenous in New Caledonia, Fiji and many Polynesian Islands (27). Where or how the roving Polynesians picked up the garden sugarcanes from the Melanesians is not known but from the evidence of anthropologists on "race" migration it is plain that transportation of the cane eastward began not more than a thousand to fifteen hundred years ago, or at least fifteen hundred years after *arrival* of the cane on its long journey northwestward to the province of Bengal.

Beginning in 1768 Tahiti became a contributing source of cane varieties, few in number but important in their impact on sugar industries, particularly on the "sugar colonies" of the New World. The subsequent complex history of modern cane migration during the next century from these islands and from all the other early centres of diversity is well summarized by Deerr (22).

The most important and extensive distributions of original noble canes during that century were from Java and other islands of Indonesia. In small groups, or even singly, a large total number of varieties were carried at different times to Mauritius and the New World sugar colonies, to South Africa, Australia and to European "settlements" in southeastern Asia. Most of the identifiable noble canes in India today trace back to shipments of that period. Soon after the sugar experiment stations were established in Java about 1880 there occurred a great backwash of sugarcane varieties to Indonesia from all sugar producing countries stimulated by the frantic search for varieties resistant to sereh[1]. Although hundreds of names were attached to the noble forms retrieved from other countries and to those gathered by intensive search in other islands of Indonesia it appears from the careful studies of Jeswiet (28) and Posthumus

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[1] Emphasis was given to the assembling of the tropical garden canes. It is significant that although wild *Saccharum* forms were not collected the primitive domesticated canes of northern India were included and their resistance to sereh generated an interest in wild canes as breeding material.

(34) that less than fifty separable forms were involved. Since in some cases these included the usual three-colour variants of otherwise identical clones the actual number of distinctly different noble forms readily available for procurement and testing at that time was considerably under fifty.

SUMMARY OF EVIDENCE ON ORIGIN AND DISPERSAL

Summarizing the evidence on geographic origin, phylogeny and dispersal of the original, domesticated sugarcane (by common consent referred to *S. officinarum*) mention has been made of :

1. Existence in New Guinea of great numbers and wide diversity of these colourful, cultivated garden forms in contrast with relatively few numbers and greater homogeneity of forms in other centres of diversity scattered from India to eastern Polynesia. Types of botanical oddities among the garden forms are found singly or sparsely in the other centres of diversity. Representatives of all types are found in New Guinea.
2. The discovery in diverse, colourful forms and great abundance of a large wild sugarcane, *S. robustum*, limited in known range to New Guinea and adjacent islands of Melanesia. The relatively small, green wild cane *S. spontaneum*, which was also found in New Guinea, has a wide range extending from eastern Africa to Melanesia.
3. The close relationship of *S. robustum* to the domesticated garden forms and the more distant relationship of *S. spontaneum* as indicated in the revised key to the species of *Saccharum*. Corroborating the taxonomic evidence an impressive number of physiological affinities between *robustum* and, *officinarum* and conversely, a number of physiological differences between *spontaneum* and *officinarum* were pointed out.
4. The postulated pathways of prehistoric migrations of the domesticated sugarcane, transported by man, and relative times of these migrations radiating from New Guinea based mainly on botanical evidence and partly on anthropological and ethnographical evidence.
5. Modification usually in slight degree of the domesticated garden sugarcane at various centres of diversity along the pathways of migration by natural hybridisation with other grasses including *Erianthus maximus* and *S. spontaneum*. Modification by hybridisation with *S. spontaneum* in the higher latitudes of the tropics was extreme and resulted in the small, thin-stemmed cultivated sugarcanes of northern India and southwestern China adapted to the sub-tropics. A few of the most primitive cultivated canes of northern India show no morphological evidence of admixture with the domesticated garden sugarcanes and they may have evolved exclusively from *S. spontaneum*.

To this evidence on phylogeny and migration of the domesticated sugarcane may be added a note on the probable course of the much earlier migration of primitive *Saccharums* to New Guinea from the continent of Asia unaided by man and the subsequent isolation in New Guinea by water barriers of *S. robustum* or other evolutionary forms developed there exclusively. This involves the geophysical evidence interpreted by geologists and the floristic studies of phytogeographers. In the latter field of work we are indebted chiefly to E.D. Merrill, whose classic studies of island floras from Asia to Australia and whose interpretations of plants in the area give the clue to our own interpretations of ancient migrations and modifications of wild *Saccharums* under conditions undisturbed by man.

The towering, mountainous island of New Guinea is unique among equatorial islands. Among island land masses it is second in size to Greenland. Reminiscent of Greenland also great fields of "perpetual" snow and ice reside on the highest peaks of the central chain. This is a condition found elsewhere on the equator only in the continental areas, namely eastern Africa and western South America. New Guinea rests on a continental shelf now submerged only 30 to 40 fathoms and including Australia to the south and nearby Halmahera to the northwest. Another continental shelf extends from southeastern Asia to include Sumatra, Borneo and Java. In a deep sea trough or basin between these two *stable* regions is an area of *instability* including the Philippines, eastern Celebes and the Spice Islands. In the Cretaceous all of these islands were part of the great Asiatic-Australian continent and apparently some Asiatic types of plants found their way to New Guinea by that land bridge but subsequently, archipelagic conditions prevailed and New Guinea has remained insular except for intermittent land connections with Australia. Theoretically, it was possible for primitive *Saccharums* to reach New Guinea from Asia and undergo modification on that unique island which did not occur elsewhere. It is clear that the modified wild forms including diverse forms of *S. robustum* have been isolated by water barriers for a long time.

COLLECTING EXPEDITIONS 1853—1951

First hand collecting of original sugarcane varieties on an ambitious scale within the area of earliest dispersal began soon after the annexation of New Caledonia by France in 1853. Colonists from Reunion in the Indian Ocean who were familiar with commercial cane cultivation on that island, and Mauritius were impressed by the wealth of colourful, sweet varieties cultivated by the Melanesian aborigines of New Caledonia and nearby islands of the New Hebrides. An active commerce sprang up between these islands and Reunion, conducted at first by sailing vessels. Colonists came in increasing numbers from Reunion bringing with them skilled labourers, sugar making machinery and the arts of sugar fabrication. During the next two decades some of them returned to Reunion with sizeable collections of the handsome garden canes from

Tanna and New Caledonia[1]. Added to the collection of Caldwell taken from the same area to Mauritius in 1870 (22) the large numbers of Melanesian garden canes carried to Reunion and Mauritius augmented the already established reputation of those two islands as important sources of sugarcane varieties. Some of these Melanesian garden canes under the names Tanna, Caledonia Queen, Caledonia Ribbon, Yellow Caledonia, Kava-rangri (Cavengerie), etc. enjoyed longer or shorter periods of popularity as important commercial varieties in a number of sugar producing countries.

Vieillard and Deplanch listed and described very briefly 40 garden canes of northern New Caledonia in 1863 (35). In 1884 de Greslan similarly described 60 different cane varieties cultivated in gardens throughout New Caledonia ; notes on their flowering tendencies were later published by Sagot (35). At the time of publication, 1893, Sagot stated that the recent introduction of cattle and the reckless manner of pasturing by the colonists had brought about the disappearance of many varieties listed by de Greslan and Vieillard. The numbers of garden cane varieties had been reduced by other events. The continuous series of violent insurrections by the Melanesians from 1853 to 1884 and, in the neighbouring New Hebrides the exploitation and debauchery of the primitive island people by swarms of lawless labour recruiters could not fail to decimate both garden canes and gardeners. The present 40,000 population of the New Hebrides is but a handful compared with what it was. The wonder is that after such violent disturbance of an ancient way of life on the southernmost islands of Melanesia the fears of Sagot regarding extinction of the small cane gardens have not materialized. In 1935 I visited villages of 18 Melanesian tribes in New Hebrides and New Caledonia and collected 126 clones of garden canes together with specimens of wild growing relatives including *S. robustum* in Efate and *Erianthus maximus* in New Caledonia.

Parenthetically, *E. maximus* is without question the tall grass collected in Tahiti by botanists who accompanied Capt. James Cook to that island in 1769 and 1772 and which was misnamed *S. spontaneum* by J. G. Forster, botanist of the second voyage. Later collectors have never confirmed the presence of *S. spontaneum* in Polynesia. This error stimulated the assertion, untenable on botanical evidence but held to by de Candolle, Sagot (35) and others, namely that domesticated sugarcane was derived from *S. spontaneum* in the Polynesian islands. Dangling from his main premise Sagot made the concession that the sugarcane might also be derived from *S. spontaneum* at high elevations in mountainous islands of "Malaya" thus encompassing as the place of origin a considerable part of the earth's surface. I have myself collected *E. maximus* in Tahiti and Raiatea of the Society Islands as well as in New Caledonia, these representing the eastern and western extremities of the natural range as known today. I have not encountered *S. spontaneum* (nor *S. robustum*) in Pacific east of the Papuasian group of islands despite a 35 year reconnaissance covering all major groups of mountainous islands. Exploring the low islands, i.e. atolls and reefs for cane would be an impossible as well as an unrewarding task. The ecological conditions of such islands are unsuitable for the garden canes and their close wild relatives as well. Garden canes can be made to grow when well tended, however, on coral atolls like Tongatabu.

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[1] Oral communication from the late M. Huet, a resident of Noumea since 1869.

The handsome group of Hawaiian garden canes appear not to have been distributed elsewhere for commercial exploitation during the 19th century as extensively as were the canes of New Caledonia and New Hebrides. Some of them must have been used locally for sugar making during the early years of the modern sugar industry but most of them were soon displaced by varieties from Tanna, New Caledonia, Tahiti and Indonesia. The early published records do not clearly recognize or distinguish different Hawaiian varieties although such distinction must have been important to the indigenous Hawaiians. During the second half of the 19th century Hawaiian cane names began to appear on lists of varieties in other countries. There is on record a formal request by the U.S. Secretary of Agriculture for Hawaiian sugarcanes during the reign of Kalakaua, 1879-1891. These were intended for the Louisiana Sugar Experiment Station established in 1885 at New Orleans as part of the state land-grant college sponsored by the Federal Government. Seven varieties listed as Ko Kea, Manulote, Uwala, Ohia, Akilolo, Honuaula and Papaa were duly received in 1887 from Wm. G. Irwin & Co. and were transmitted to New Orleans by the American consul at Honolulu. Incidentally, the device of importing plant varieties by courtesy of U.S. State Department missions abroad was employed by the U.S. Patent Office long before the U.S. Department of Agriculture was set up as an executive department in 1862. The 30 or more Hawaiian garden canes in our collection represent two shipments sent to the U. S. D. A. by courtesy of the Hawaiian Sugar Producers' Association. According to advice from the H. S. P. A., the second shipment was sent to remedy mislabelling of varieties in the initial shipment. They were originally assembled as a collection for study on the island of Maui beginning in 1920 by W.G. Moir and Edward L. Caum. As part of the world reference collection the fairly homogeneous group from Hawaii has been further studied in relation to other groups and has provided some of the evidence leading to interpretations in preceding sections of this paper on the origin, dispersal, modification, diversity, etc. of the noble canes.

The second series of large scale collecting expeditions to Melanesia began in 1893 when the Queensland Department of Agriculture commissioned Ebenezer Cowley to collect economic plants, including sugarcane, in British New Guinea. The Queensland Acclimatization Society previously had been active in obtaining cane varieties from Mauritius and Indonesia for the expanding sugar industry. In some ways the collecting of cane varieties in New Guinea for Queensland paralleled the variety collecting in New Caledonia and New Hebrides for Reunion several decades earlier. Both followed immediately the formal annexation of new territory and both were sponsored in part by government and in part by private enterprise. Although the journey from coastal New Guinea to Queensland is much shorter than the corresponding voyage from New Caledonia across the Indian Ocean to Reunion the problems of seed cane survival were formidable because of the immense size and rough surface features of New Guinea and other surprising difficulties of interior travel. A walk across central New Guinea is an undertaking of almost a half year and needless to say the first sugarcane collectors did not operate far from the coast, although the Colonial Sugar Refining Co. expedition under A.M. Carne crossed the narrow but mountainous eastern peninsula in 1914. Success of the collecting projects has been varied. The pioneer venture of the Queensland Department of Agriculture under Mr. Cowley in 1893 met the fate of many pioneers. Not a single variety was established in Queensland. The buds were either dead on arrival or were killed by fumigation. A second trip by Mr. Cowely the same year resulted in establishing eleven varieties at the Kamerunga State Nursery. Without question these experiences were of value in opening the eyes of the competent authorities to the need of careful planning and the Department's next expedition under Mr. Henry Tryon in 1895 was better organized.

Mr. Tryon was a trained entomologist, botanist, and phytopathologist. Thirty three years after his noteworthy collecting, I had the privilege of meeting Mr. Tryon in Brisbane. A small, white whiskered, taciturn individual, he impressed one as a meticulously careful man who could be trusted to anticipate the needs and work out beforehand the requirements in a difficult job of collecting perishable cane cuttings. With two other officers of the Department he chartered a cutter at Thursday Island and prudently limited his operations to a short stretch of the south eastern coast, emphasizing the procurement of propagating material of each variety in superabundance. In about four months cane plants and packing material weighing more than 7 tons were collected and taken by cutter to Cooktown in northern Queensland thence to Cairns, the railhead, thence by special train to final destinations. With careful planning and good luck, except for a storm which drove the cutter west to the Gulf of Papua, only 200 lbs. of cane plants were lost because of unavoidable delay in handling. Sixty-six varieties were carefully nursed from New Guinea to Queensland and New South Wales, among them the famous Badila which paid for the cost of the expedition and probably for much of the subsequent research of the Department for the next half century.

An enlightening historical account of Tryon's and other sugarcane collecting expeditions to New Guinea together with an excellent narrative of their own expedition in 1951 has been given by Buzacott and Hughes (20). All told there have been ten collecting ventures, five by the Queensland Department of Agriculture (1892, 1893, 1895, 1912, 1951), three by the Colonial Sugar Refining Company (1908, 1914, 1921), one by the U.S. Department of Agriculture (1928) and one by the Hawaiian Sugar Planters Association (1938).

Up to and including the 1921 collecting in New Guinea the chief objective was to discover better garden canes, *S. officinarum*, for direct exploitation in plantations. No interest had been taken in wild *Saccharum* forms and, in fact, there were no authentic records at that time of the existence of such wild forms in New Guinea.

Renewed interest in the New Guinea garden canes, and in particular an active curiosity concerning their phylogeny, which stimulated the next collecting expedition in 1928, was brought about indirectly by a disease epidemic. For several years prior to 1921 and continuing thereafter the ominous virus disease mosaic, long endemic in the *highland* native gardens of Java, had been encroaching on the sugar producing countries of the New World, one by one, beginning in Argentina where the disease was first introduced inadvertently on *noble* x *barberi* hybrid canes directly from Java[1]. Like the garden canes themselves this virus must have originated in New Guinea where it is endemic but rather rare because the tiny gardens are widely spaced and buffered by dense forests which are obstacles for the insect vector. It is characteristic of sugarcane mosaic that it becomes epidemic, accompanied by sharply diminishing crop returns, only in humid, grassy areas where sugarcane is a monoculture. Waves of epidemics under such conditions are dictated by the character of seasons which influence populations of the insect vector *Aphis maidis* and also the development and flights of their winged generations.

As early as 1919 evidence of group reactions to infection of three taxonomically separable classes of sugarcanes was observed (10) and objectives for control of mosaic gradually became defined involving extensive taxonomic studies of noble, primitive and wild growing sugarcanes. There was precedent in the old sereh investigations for the anomaly that basically important botanical studies were supported incidentally as an adjunct of pathological studies. In 1922 and 1923 I searched for mosaic resistant noble and wild forms and their hybrids in the western Pacific and far eastern countries and always, as in the case of the variety Toledo (12), a component of wild cane appeared or was suspected in the ancestry of resistant forms. Variations in the severity of reactions of noble canes to the virus prolonged our hope that resistance might be found in them also. The global spread of mosaic and the accumulating evidence on susceptibility of all *S. officinarum* forms, reaching almost to the saturation point (12, 37) in humid areas, prompted the idea of the world reference collection of original sugarcane varieties described in the first paragraphs of this paper. Obviously the rich assortment of Melanesian canes including feral forms that we confidently expected to find in New Guinea could not be excluded.

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[1] When the sugar experiment station at Tucuman, Argentina, was established the directorship was offered to Dr. Jan Kobus. As a herald of his coming Dr. Kobus sent from Java the Cheribon×Chunnee hybrids P.O.J. 33, 36, 105, 139, 213, and 234, but the negotiations broke down and he did not follow. From Tucuman, cuttings of these hybrids were sent later to Puerto Rico, where in 1919 they were found to be 100% infected with the "new" disease mosaic. Reaction to the disease by these hybrids, however, was quite mild compared with the severe reaction of the noble canes then grown commercially, a circumstance that interested me in their ancestry.

A strong effort was made to launch the New Guinea phase of the collecting in 1924, first as an independent, federal government expedition and later in the same year as part of a private plant hunting expedition to the far east. Both efforts failed and that important phase of the collecting did not come off until more than three years later in 1928.

These setbacks proved rewarding in two ways. More time was provided for (1) consideration of the logistics involved in covering an immense area to collect perishable plant material and (2) study of what reasonably might be predicted in the way of finding primitive precursors of garden sugarcanes in New Guinea. As to solution of the first problem it became plain to me that despite the complete absence of charted airways and gasoline depots in New Guinea a large seaplane was preferable to a boat; better even than the boat we had hoped to use in late 1924, a specially designed one equipped with deck greenhouses.

The second problem of what feral forms reasonably might be predicted called for persevering study on the more quiet front of library research. Essentially, there was no technical literature in the abbreviated language of science and no herbaria with Papuan collections worthy of the title. The most prolific reporters on New Guinea and practically the sole representatives of science were, in those days, the anthropologists. Physical geography including weather and brief comments on flora had to be dug up and interpreted from voluminous printed, typewritten and even handwritten manuscripts, mostly on other subjects by non-specialists including those of an assortment of adventurers with cameras and guns who were attracted by the unknown even as dedicated scientists are attracted. There is a surprising amount of literature of that type on New Guinea, some of it going back to the closing quarter of the 19th century. Searching for particular fragments significant in our inquiry and testing their credibility may be likened to reading right through the unabridged dictionary from A through Z to find a few significant words and more or less enlightening definitions.

"Wild cane" and "wild sugar cane" had been mentioned in a vague and casual manner for 40 years or more in reports and books by missionaries, explorers, government patrol officers and the government anthropologists. In the majority of these casual references to wild canes it is found impossible to determine whether a grass or a palm (rattan) is meant. In other cases there is no doubt that reference was to a fairly tall wild grass. In still others a careful study of the references in context, especially where repeated several times with allusions to the environment, extent and compactness of the colonies of plants, the labour of hacking a path slowly through the growth with a cutlass, and the attendant great danger of accidental fire, gradually unfolds a picture which practically proclaims "I am *Saccharum*".

For one experienced in the observation of *S. spontaneum* in gregarious and more or less extensive associations in natural habitats of the Philippines and Indonesia there could be little doubt that *spontaneum* was the plant referred to in some of the more vivid writings. *S. spontaneum* was not only present but apparently present in both wet and xerophitic associations. The pay-off for voracious reading of botanically sterile matter came with several brief allusions to "wild sugar cane" much taller and with inch-thick stems so tough that in a thicket, without room for a full swing, the cutlass rebounded like peas from a tight drumhead. The thick pure stands were mentioned incidentally as bordering watercourses in the highlands and, in more extensive gregarious associations on the banks of broad, meandering flood-plain rivers where it could be assumed they were subjected to periodic inundation only. These pioneering bushwhacker's brief commentaries fitted the concept of wild, and large, *Saccharums* and together with the theoretical considerations described under "geographic origin and dispersal" they helped to corroborate that in New Guinea, if anywhere, one should seek the ancestral forms of the domesticated sugarcane. New Guinea became, so to speak, the bull's eye of the target and to New Guinea in 1928 we directed our steps. Upon my strong urging Dr. J. Jeswiet had accepted temporary employment and had agreed to accompany me. He had previously expressed himself as convinced that direct derivation of *S. officinarum* from *S. spontaneum* was "impossible" (30) but on the place of origin of *S. officinarum* he followed Sagot (30, 23) whose rather inclusive theories we have already mentioned in this section.

In communicating these findings to Dr. Jeswiet and discussing them before leaving Washington and enroute to New Guinea he fell into the habit of referring to "the possibility of there being more than one species which has been crossed to produce the noble varieties" there, and I find the quoted remark published in Australian newspapers a month before we ever saw New Guinea.

The same forecast was written into supporting papers of the formal letter of authorization for the expedition, issued to me a month or more before leaving Washington. These details should be interesting, I believe, and they are given as an example of predicting the existence of a new *Saccharum* species ancestral to the noble canes at a time when most botanists were content with the old one, *S. Spontaneum.* They also explain my reference in a previous section of this contribution to the "not unexpected discovery" of *S. robustum.* My devout hope that we might discover in the new, primitive New Guinea species genes transmitting resistance to mosaic was doomed to failure, as with a little more reflection, I should have suspected. *S. robustum* is just too close, physiologically, to the noble canes and consequently they are heir to the diseases that afflict *S. robustum.*

The relative disease resistance or susceptibility of *S. robustum* and its derivatives to other serious diseases may prove to be quite the reverse. Reference has been made herein to the significant fact that in the hybrids now constituting the world's commercial varieties recent invasions by the fungus *Ustilago* are accountable through the *spontaneum* line and such evidence as we have at present indicates that the same is true of ratoon stunting. In our reference collection of groups, all of which are subjected to the same field exposure, the *S. robustum* and *S. officinarum* groups are markedly less affected. At present this is merely a projection but extensive, carefully controlled inoculation experiments are indicated.

The collections of 1928 in New Guinea comprised 163 clones classified as 141 *officinarum*, 10 *robustum*, 7 *spontaneum*, 5 (recent) hybrids of *officinarum-robustum* and one *robustum-spontaneum*. The accessions were carried by air from widespread places in the Territory of Papua, Territory of New Guinea and Netherlands New Guinea at irregular intervals in lots of 5 to 25 to Port Moresby. There the cuttings were treated in Bordeaux mixture, the ends dipped in paraffine and stored at 45°F, some of them for as long as 65 days, before being carried to a quarantine greenhouse of the Colonial Sugar Refining Co. at Sydney. There was 10 to 15% loss of clones. In addition to the 1928 collections we received by courtesy of the Bureau of Sugar Experiment Stations, Brisbane, and the Colonial Sugar Refining Co., Sydney, all surviving clones of their previous New Guinea collections of noble clones. Most of these clones were eventually established during the next two years in greenhouse quarantine near Washington and at Djamba Gedeh, Java, and of course, in Queensland. Some of the wild forms which are difficult to ship successfully required two or three successive shipments. Three important clones, including *S. robustum sanguineum*, which I discovered on the banks of Sepik River 500 miles from its mouth, were lost and required recollecting on special trips back to the natural habitats by collaborating missionaries and government patrol officers. The last of the three clones was finally established after nine years of effort, a fair measure of the difficulties of terrain and remoteness of these habitats. An illustrated narrative account of the cane collecting with maps showing a few territorial features discovered from the air was published in the National Geographic Magazine (13).

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Mr. R. R. Panje then presented the following two papers.

Paper

STUDIES IN *SACCHARUM SPONTANEUM* A NOTE ON THE OBJECTIVES AND SCOPE OF WORK

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The objective of the Spontaneum Expedition Scheme, as stated in the preamble to the project-proposal is "a thorough exploration, collection and botanical study of the characters of the various types of *Saccharum spontaneum* and allied grasses......for utilizing them in breeding" (Dutt 1945). The project was conceived of as a long-term undertaking, since both the exploration and the study were to be taken up over a broad-based programme. In this note it is proposed to define in detail and as precisely as possible the objectives of the project and to discuss the orientation of the various contributory aspects of the work towards these objectives.*

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*The writer is grateful for the appreciation expressed by the International Society of Sugar Cane Technologists at their 8th Congress, of the work undertaken in the Scheme. It has been suggested, however, that it would have been better to collect the noble original cane clones first, rather than wild canes, since the former are likely to go out of cultivation with the spread of the modern commercial canes (Proceedings p. 410). It may be pointed out here that within

The aims of the Spontaneum Expedition Scheme are partly economic and partly academic. Since the purpose of the academic studies is to acquire information bearing on sugarcane breeding and varietal selection, in the ultimate sense these also have a utilitarian bias. The economic objectives of the study are obvious to sugarcane breeders and botanists. The experience of two generations of sugarcane breeders in different parts of the world has cumulatively favoured the use of *Saccharum spontaneum* in breeding. There are over a dozen characters which breeders have reported as having recovered in their seedling and for which they hold *S. spontaneum* to be parentally responsible (Venkatraman 1927, 1938, Jeswiet 1929, Posthumus 1929, McIntosh 1930, Stevenson 1939, Brandes *et al* 1938, 1939. Abbott 1938, Dillewijn 1946). These cover a remarkably wide range (Panje and Rao 1954). Officinarum has been successfully crossed with all the other species of *Saccharum* and seven species of other genera, but none of the crosses has been so useful as that with *S. spontaneum* in the matter of yielding good assortments of seedlings and progenies with a wide range of potential adaptability. Some of the world's finest and most successful commercial sugarcanes have been derived from the nobilization of spontaneum. It is, therefore, believed by many cane breeders that a good store of useful genes might be available in this species : the Spontaneum Scheme is the outcome of this view. The acquisition of breeding stocks and their comparative evaluation in terms of the characters possessed by them is the first, utilitarian, objective of the project.

Admittedly, selection is as desirable in the case of the wild parent as it is in the case of the noble parent ; and while no predictions can be made, it would be reasonable to hope that selection among wild variants would go some way towards reducing, in the words of Stevenson, the empirical element in sugarcane breeding work. But this 'somatic' evaluation of the clones, however important and necessary, is only the first half of the task, for the assurances that its results appear to carry can be confirmed and realised, if at all, only after a careful testing of the progenies of the selected variants.

Assessing the breeding value of the various types of spontaneum is therefore the second utilitarian objective of the project. To-date, on the basis of a preliminary survey of the agronomical and other characters of the collected variants, about 20 clones have been selected as possible genetic stocks (Panje and Rao 1954). Breeding tests have been in progress on a moderate scale during the past few years, and in the case of certain variants, a few promising seedlings have been obtained (Krishnaswamy 1953).

The other aspect, having an academic complexion, is less simple. This

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the limits of the Indian sub-continent, the clones of cultivated canes, viz. *S. officinarum, S. barberi*, and *S. sinense* have already been thoroughly surveyed and collected by earlier workers (Barber 1928). The objectives of the present proposal are centred largly on *saccharum, spontaneum,* and since the programme includes both a survey and a comparative study, the work necessarily involves a thorough collection.

aspect aims at understanding the variation pattern in the species as a whole, the bases of adaptation in the species and the inter-relationships between the various groups and populations comprising it. Owing to the inter-fertility between the species and there dependence to a large extent on vegetative propagation, a high degree of heterozygosity persists in most, probably all, the species of *Saccharum*; the variation in some of the species is wide and the taxonomic distinctions between some are not as sharp and clear-cut as in most sexually-propagated cereals and other grass-species. If the constitution of the various species of *Saccharum* and inter-relationships within and between them are to be understood, it can only be done through what is now being called the biosystematic approach. The aim here is only to get an insight into the operative factors and the behaviour of the various groups as they occur and propagate in nature, and not to arrive at any final decisions on the taxonomy of *Saccharum*, though of course, the position in this regard may become clearer than it is now as a result of the information gathered.

Of the five species in the genus *Saccharum*, variation under natural conditions can be studied only in the two species, *S. spontaneum* and *S. robustum*, since the other three species are not known to occur in the wild state. Of the two wild species, *S. spontaneum* has an extensive geographical distribution hemisphere, and is adapted to a variety of ecological conditions, while, in the eastern *S. robustum* has comparatively a restricted distribution, being mostly confined to the New Guinea area. Judging by gross morphological characters alone, the variation in spontaneum is much wider than in robustum, and is possibly co-extensive with it, and spontaneum is adapted to grow in a far wider range of habitats than is robustum. As far as at present known, it has a greater range of chromosome numbers and is sufficiently closely related to the three species of cultivated canes. It is, therefore, a 'fertile' material for biosystematic studies. The facts disclosed in its survey might provide a large number of clues for elucidating the corresponding problems in the allied species; indeed, some of the characters properly pursued might find the other species intra or extra-polated in the character-spread. One may also reasonably expect that inferences drawn from a study of its variation, composition and adaptation will have useful implications on sugarcane breeding and varietal work, apart from the employment of its genetic stocks in breeding.

Biosystematic studies on plant groups have in recent years attained great importance. In its present trends, this discipline aims, not merely at supplementing the classificatory function of taxonomy, but at understanding the very basis of species formation and the dynamics of organic evolution. In a major part of the work on plants done to-date, inter-relationships between groups are interpreted through intensive morphological studies made on natural populations adequately sampled. In an increasingly large number, the relationships have been based on cytological findings. Cytogenetical evidence has been used to throw light on the origin and evolution of many taxa. In certain categories of plants, anatomical investigations have been instrumental in revealing relationships which would have been difficult to deduce by other methods. Histology has taken a share in a role so long reserved exclusively for morphology. In several instances, the importance of ecology as the basis for the isolation of groups has been demonstrated. The biosystematic approach has thus a wide perimeter, and the scope that it affords for counter-confirmation adds greatly to its value.

On spontaneum and other species of *Saccharum*, the work done in the past is practically confined to the morphological and cytological aspects. In *Saccharum spontaneum* the existing taxonomic subdivisions were revised through morphological observations on 12 clones assembled from certain areas (Panje 1933). Artschwager (1942) has described the morphological characters of a number of forms. Chromosome numbers are now known of about 74 variants (Akira Moriya 1941 ; Parthasarathy and Subba Rao 1946). These studies have given considerable insight into the species, and brought out the need for a detailed survey which took into account the ecological and other aspects.

The principal sectors along which work is now in progress are five in number ; the morphological, the cytological, the ecological, the anatomical and the chemical. Of these, the morphological aspect is the most important. In the study of morphological variation, two methods are distinguishable. One is the extensive survey of one or a small number of characters over a wide range of distribution of the group. Studies of this kind have been carried out by many investigators. The other is the more intensive study involving correlations of a fairly large number of characters recorded over a limited area of special interest. This kind of approach has been typified in the work of Anderson (1949 and earlier). In the spontaneum work, the survey is necessarily planned on the first method, but the number of characters available is large, and their correlations can be investigated. The main body of observations is made on the variants under the uniform environment of a garden assembly, but since most of the SES variants have been collected through personal visits and exploration in the different areas by the writer, a fair assessment of the effect of displacement from the original habitat is also possible.

When isolated lines of investigation in morphology or cytology are supplemented by observations on the ecological aspect, a distinct insight can be had into the behaviour of the populations in nature. In the spontaneum work, the ecological information collected forms the essential background of all studies. Besides notes on the environment, observations are made on the density of distribution, propagation and spread, local variation, flowering and the general behaviour of the species in the region. Some of these observations have direct implications on the principal objectives af the work ; in all cases, they give a great deal of insight into the characteristics of adaptation of the species and factors affecting the survival of its biotypes in nature.

With the ecological aspect are also being considered one or two physiological attributes of the variants, at present the ones most closely connected with drought resistance, such as the osmotic concentration of the cell-sap. It is difficult to say how far they would show correlations with the ecological or geographical distribution, as the relationships between the plant and its environment are governed by many factors. But it is hoped that duly supplemented by other data, they would throw some light on the behaviour of the variants in nature and also give some guidance on the selection of clones for use in breeding.

In the cytological aspect, at present the objective is confined to an extensive survey of chromosome numbers. The counts so far have had to be made solely from iron-aceto-carmine smears of pollen-mother cells. Many variants, however, failed to flower at Coimbatore ; since 1953, the entire collection has been duplicated at Karnal in the Punjab, and the needed material is being obtai ned from there.

In the anatomical aspect, the surveys so far done are of the epidermal cell pattern, and of the sizes of pollen grains, stomata, long cells of the epidermis and the plastids. Some of the latter characters have shown interesting correlations with ploidy in chromosome numbers (Rao and Balasubramaniam 1953).

As in many other studies, the major task is not often the survey itself, but the sampling. Growing the variants in the same environment eliminates certain sources of non-genic variation, but does not eliminate the variation within the individual plant or clone. This difficulty is usually attempted to be got over either by taking a sample large enough to cover the variation, or by standardising the sample. The latter method presupposes a knowledge of the pattern of existing variation, but more often than not, this prior knowledge is not had. A digression has had therefore to be made in many cases in order to understand these narrower sources of variation. Leaf morphology is one such instance.

In investigations on the chemical line, a survey of juice-quality of the variants has been first carried out. The primary purpose of this was the selection of genetic stocks. It is very much to be doubted that sucrose content of stalks would have a significant place in the natural variation pattern of spontaneums. On the other hand, investigations on monosaccharides in the clones may prove interesting. Work is in progress on this aspect. A survey has also been carried out on the presence of starch in the internodes.

In addition to these, many other investigations are on hand, such as disease and pest susceptibility, flowering protogyny, pollen-fertility, floral abnormalities, etc., some of which have yielded interesting information. Rao, for instance, has found that protogyny is to some extent associated with polyploidy and possibly also with geographic distribution (1954). Studies on disease and pest susceptibility have a dual value : on the one hand, they are important criteria in the selection of genetic stocks ; on the other, they may bring out certain biotic relationships. I n all cases, the observations may clarify and lead to a fuller understanding of the species in its various facets.

Lastly, a mention must be made of agronomic characters. Genetic stocks can easily be selected on the basis of individual characters such as tillering capacity, height of stalk etc. But the basic and somewhat intangible problem in varietal work is the question of the totality or combination of these characters of vegetative proliferation as expressed in each variant, and the inherent conformity of these combinations to the environments of the concerned variants. It is perhaps the combination of characters rather than any single morphological or agronomical character that should be considered as the basis of adaptation. This question has an important bearing on varietal selection work in India. We know that different varieties of cane turn out to be suitable to different areas, but we really have no information on the actual basis of varietal suitability. It is possible that the suitability or otherwise of varieties to different areas is based on a single character, such as, say, drought resistance or quick germination capacity, the particular character being crucially selective in relation to a corresponding limiting factor governing a particular environment. If such be the case, then a variety merely good enough in this particular character may turn out to be the best for that area. On the other hand, it may be that the entire growth-pattern of the variety reacting with the environmental pattern is concerned with the phenomenon of adaptation. This aspect has been discussed by the writer in an earlier note (1953). Certain studies have now been conducted in order to find out whether the growth-patterns of spontaneum-variants show any conformity with their own environments and non-conformity with those of the others, and what is the degree of their tolerance. The reason for doing this kind of study on spontaneum variants rather than on cultivated canes is that the former are nature-selected and their study would reveal the natural factors which have effected the selections.

To summarise, the basic assumptions underlying the work of the Spontaneum Expedition Scheme are two : the first is that the species contains a wide assortment of genes likely to be useful for sugarcane breeding ; the second is that in its striking variation and high adaptation there might be many interesting facts of bio-systematic importance, and some of these facts may also have important bearings on cane breeding and varietal selection. If these assumptions are correct, the best way to collect the information (and the material) is by means of a thorough exploration and survey and a comprehensive programme of investigations covering many aspects. It was along these lines that the work of the project has been conducted since 1950. To-date about 400 clones have been collected or imported and considerable progress has been made in the studies. With this outline as an introduction, the results of the various studies conducted will be discussed in subsequent papers.

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Paper

STUDIES IN *SACCHARUM SPONTANEUM* GEOGRAPHICAL DISTRIBUTION OF THE STARCH CHARACTER IN INDIAN SPONTANEUMS

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The presence of starch in the cells of the stalks of certain cultivated sugarcane varieties, in addition to the sugar in solution, has been reported from time to time. Hadden (1927) found an appreciable quantity of starch in the stalks of the variety Uba, but none in the thicker types of cane. According to him, canes grown in acid soils had fair quantities of starch in the stalk, while those grown in alkaline soils were devoid of it. This observation was confirmed by de Sornay (1927) and Feuilherade (1928). The latter author found that while in H. 109, D. 1135 and certain other varieties starch was restricted to 2 or 3 rows of cells surrounding the vascular bundles, in Uba it was distributed throughout the cross section, both in the sclerenchymatous and parenchymatous cells. Von Steiglitz (1932) was of the opinion that the age of cane and climatic conditions bear greater influence on starch formation than soil reaction. Although the above studies were primarily concerned with the presence of starch as affecting the quality of juice, varietal differences have, as quoted above, been observed between the thicker types of cane and Uba in the content of starch and the cells concerned in its storage.

Dutt and Narasimhan (1951) have shown that qualitative differences in starch content in the internode are fairly closely associated with taxonomic differences at the generic and specific levels. Thus they found that in *Saccharum officinarum* and *S. robustum* no starch is stored in the cells, whereas the *S. sinense* varieties show fair quantities of starch, and in *S. barberi* and *S. spontaneum* the accumulations are quite marked. Apart from its value as a distinguishing character, they found that presence or absence of starch was indicative of affinity and phylogenetic relationship.

While studying the inheritance of various morphological characters of a hybrid between P.O.J. 2725 and *Miscanthus japonicus*, Chun Fu Chen (1954) found that the internodal parenchyma cells of *Miscanthus japonicus* and of the hybrid (36-771) contain small starch grains, while the female parent is devoid of it. This is considered by the author as the manifestation of the dosage effect of the M-genome from *Miscanthus japonicus*.

MATERIAL AND METHODS

In the Spontaneum Expedition Scheme, the variants of *S. spontaneum* numbering about 400, inclusive of about 100 from outside India and covering the geographical distribution areas of the species, are under study for understanding the pattern of variation in the species and for their evaluation as possible breeding stocks (Panje 1956). In a study of variation in the species it was found that the presence of starch in the stalk cells was not a constant feature of all variants, that it was subject to variation, and that there was a large number of forms in which starch was wholly absent. In this paper a survey is made of this variation among the Indian *spontaneums*.

All the variants available in the collection to-date have been examined for starch content. Cross sections were cut from the middle portion of mature joints of full-grown stalks, tested with iodine and the degree of starch accumulation was recorded under a microscope. The amount of starch present was classified under the three categories 'no starch', 'small quantities', and 'large quantities', as done by Dutt and Narasimhan (1951).

OBSERVATIONS

Tests on seasonal and ontogenic variation

In view of the fact that starch is a stored product of metabolism, and is therefore presumably liable to fluctuation, it was felt necessary first to study the possible diurnal and seasonal variations. For studying diurnal fluctuation, round-the-clock tests with 3-hourly determinations were conducted on a few variants. In these observations no changes were noticed in the amount of starch in the cells. For studying the seasonal variation, the variants were examined for starch in the months of May, July, and October, covering both the vegetative and the flowering phases of the growing stalk. These tests, made in two successive seasons, failed to show up any changes in the starch content. No differences were observed in the amount of starch between erect and trailing shoots of the same variants, nor between the flowered and non-flowered stalks. It thus appears that the starch content of the stem of a given variant at the mature stage is more or less constant and can be considered quantitatively as a characteristic feature of the variant. It is not known whether the transplantation of the clone from its original habitat to Coimbatore had any effect on the expression of the starch character, but this seems unlikely. All the variants surveyed in this study had been grown in the same environment at Coimbatore, but the differences in starch content were as well marked as between different species of *Saccharum*.

Starch content in the internode and the root zone are positively correlated though there are some exceptions to this. The size of the grain and the number of grains per cell were positively correlated ; in other words, where the number of grains was more, the average size of the grain was also usually larger.

RESULTS

The geographical distribution of the starch character in Indian *spontaneums* as brought out in these studies is presented in Fig. 1. A study of the map shows that the distribution of the starchy, semi-starchy and non-starchy *spontaneums* in India is not quite uniform. (i) In a large triangle forming central and western India, and comprising the Deccan, the Vindhyan uplands and the Chhotanagpur hills, the *spontaneums* represented in the collection are almost all devoid of starch. (ii) In a long strip bordering the Himalayas from Jammu to Sadiya, in the eastern states of West Bengal, Assam, the North-East Frontier Agency and Manipur, and in the South-eastern part of Orissa, there is a striking predominance of the farinaceous forms ; in the westerly arms of this area *spontaneums* of lower starch-gradations also occur in fair numbers. (iii) In the peninsular areas south of Deccan and Orissa, the number of starch-less and medium-starch forms is about equal; in addition, there are a few starchy ones.

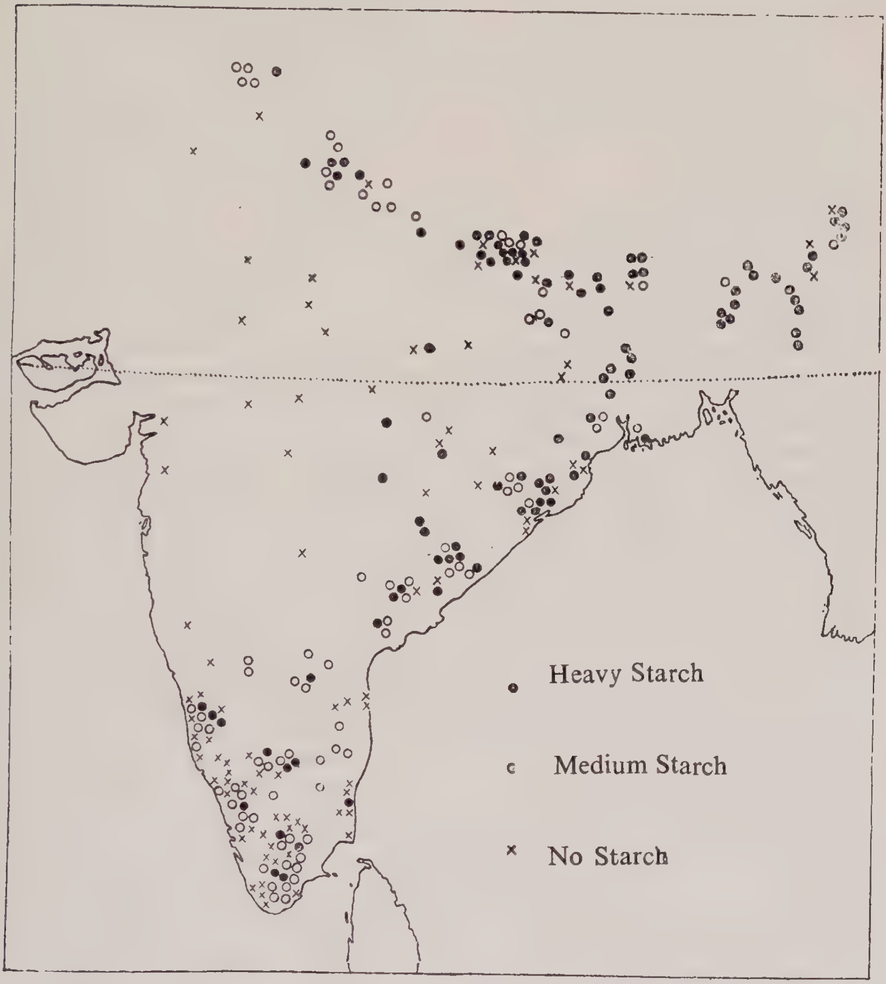

Fig. 1. Map of India showing the distribution of starch character in Indian spontaneums.

The frequencies in these three areas are given in Table I.

TABLE I

DISTRIBUTION OF STARCH CHARACTER IN DIFFERENT AREAS OF THE INDIAN SUB-CONTINENT

Geographical area	Number of variants recording		
	No starch	Medium starch	Heavy starch
1. Central and Western India	**24**	**1**	**4**
(a) Deccan and western uplands	19	—	—
(i) rainfall less than 30″	2	—	—
(ii) rainfall between 30″ & 50″	17	—	—
(b) Mahanadi basin and Chhotanagpur (rainfall more than 50″)	5	1	4
2. Northern, Eastern and South-eastern India	20	39	83
(a) Western terai			
(i) rainfall less than 30″	1	—	—
(ii) rainfall between 30″ & 50″	1	16	7
(b) Central terai (rainfall 50″)	8	10	20
(c) Eastern terai (rainfall more than 50″)	4	2	29
(d) Ganga and Mahanadi deltas (rainfall more than 50″)	6	11	27
Distribution in areas 1 *and* 2 (*above*) *classified on rainfall basis.*			
(i) Areas of less than 30″ rainfall	3	—	—
(ii) Areas of between 30″ & 50″ rainfall	18	16	7
(iii) Areas of more than 50″ rainfall	23	24	80
3. Peninsular India south of Deccan	52	67	18
(a) Western and Eastern Ghats and their submontane areas	34	41	12
(b) Non submontane areas	18	26	6
Distribution in area 3 (*above*) *classified on rainfall basis.*			
(i) Areas of less than 30″ rainfall	10	71	3
(ii) Areas of between 30″ & 50″ rainfall	14	23	10
(iii) Areas of more than 50″ rainfall	28	27	5

DISCUSSION

The characteristics of these three tracts have been described in some detail in an earlier paper (Panje 1954). The Deccan plateau, the Vindhyan uplands and Chhotanagpur hills, have an elevation of from 1000 to 3000 ft. The climate is on the whole dry and mildly continental in character. The north-western parts of this area are more arid than the south-eastern. The second tract includes the entire terai-dooar belt and the river basins ; except for the Gangetic valley, these areas are all either submontane or deltaic. The third tract, which is somewhat mixed in character, comprises the deltas and plains of the peninsula (the Mahanadi delta being included above) and the Eastern and Western Ghats.

Among the many major environmental factors that contrast the first two geographical subdivisions, is the intensity of rainfall. The Central Indian expanse which is characterised by non-starchy variants has on the whole a low rainfall, while the terais and the eastern states which show a predominance of the starchy types have a high annual precipitation. In the third subdivision, viz., the peninsular area, the distribution of starch, semi-starch and non-starch forms seems to be random, but there is a faint indication that the heavy starch types tend to occur in and about the hill ranges and the high rainfall areas.

This is brought out by a comparison of Fig. 1 with Fig. 2 in which are given the principal isohyets, physical features and river valleys of the Indian sub continent. The 50 inch rainfall line separates out the terais, river basins and deltas of the north-east and south-east from the central Indian area. It is interesting to observe that even in the Central expanse, such few of the heavy-starch and medium-starch forms as at all occur, fall within its south-eastern part where the rainfall is over 50 inches. Again in the western terai and in Central peninsular area, the heavy and no-starch forms seem to yield place to the semi-starch ones ; this is in keeping with the fact that in these areas the rainfall is less than elsewhere, being between 30 and 50 inches per year.

In the peninsular area there are only two narrow belts, wherein the annual rainfall exceeds 50 inches one along the west coast covering a good part of the Western Ghats and another just grazing the Cauvery delta in the east coast. About half the number of starchy forms occur in these belts, the remainder falling in areas of lesser rainfall. Twelve out of the 18 are located in montane and submontane areas.

What precisely are the factors affecting the distribution of the three starch-grade types can only be a surmise at this stage, at best a first approximation. Although on the ground that the first two areas are subtropical and the peninsular tract is tropical, the factors controlling distribution can conceivably be different, yet it would be reasonable to expect that the factors operative are the same in all the tracts. Very possibly, the factors are identical. It may be pointed out that even in northern India, the areas of predominance of starchy forms are as in the peninsula, mostly the submontane ones. Possibly, both rainfall and factors concerned with submontane orography are influencing the distribution. Indeed, the more direct association may be not with the overall meteorological or orographical factors, but with others which they give rise to : among these are high relative humidity, high soil moisture, high sub-soil water level and even afforestation and soil acidity, and these also characterise most of these areas ; but so close a basis for association is difficult to trace out in a survey conducted on the present scale.

The possible association of soil acidity in the selective distribution of *spontaneum* might seem to be of interest because of Hadden's and Feuilherade's observation that sugarcanes grown in acid soils develop starch. It is conceivable that soil acidity is an environmental factor favourable to the phenotypic

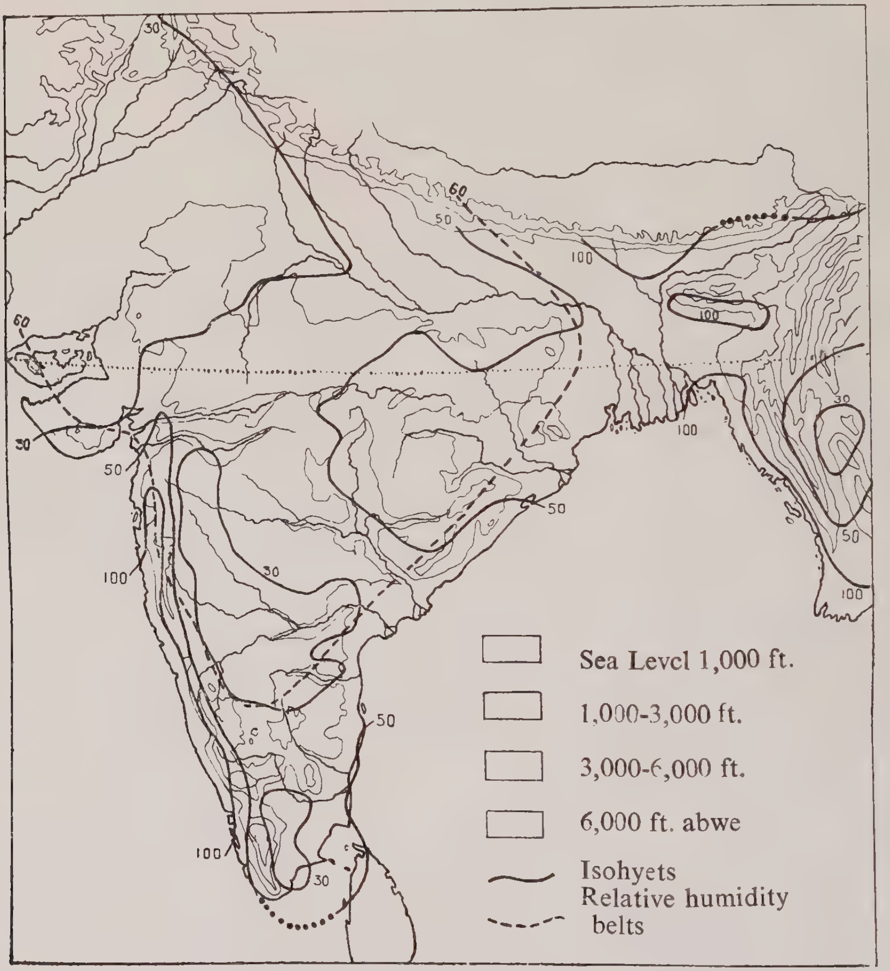
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Fig. 2. Map of India showing Physical features and Isohyets.

expression of starch-genes where they are present, but it must be pointed out here that almost all the clones surveyed in this study have been grown under uniform conditions at Coimbatore (where incidentally the soil is slightly alkaline) ; the differences observed have therefore obviously to do with the distribution of genotypes rather than with the more superficial effects of local environments.

There is another factor the influence of which should not be overlooked in understanding the basis of the distribution pattern ; this is the degree of prevalence of sexual propagation in the species in the different areas. As will be discussed in a future paper, in the more arid areas, namely central and north-western

India, the propagation is mostly sexual, and the distribution would tend to be more uniform. In other areas, where conditions are more generally favourable, vegetative propagation is likely to result in the preservation of a wider range of clonal variation.

It will be noticed from the map (Fig. 1) that the difference in distribution as between Central India on the one hand and Assam on the other, is quite sharp ; the one has almost entirely starch-less forms while the other has largely heavy-starch forms. This is suggestive of a high selection pressure in these two contrasting areas. The association of semi-starch forms with the submontane but lower rainfall areas, viz., western terai and central area of the peninsula has also been referred to. Elsewhere, there are mixtures of all the three kinds, e.g. in the central terai belt, in the Gangetic valley and in the peninsular area in general. The occurrence of mosaics of habitats in the submontane (terai) areas has been mentioned by Panje (1954). The persistence of the different types is possibly due to this variety of habitats, although an attempt to correlate these local habitats with individual clones was not quite fruitful. Apparently, where conditions are favourable enough for both the starchy and non-starchy forms to exist side by side, a certain amount of gene exchange is taking place between them, and the medium-starch element is able to persist because of continuous natural crossing, aided by vegetative propagtion.

SUMMARY

In a study of variation in *Saccharum spontaneum*, it was found that the presence or absence of starch grains in the internodal parenchyma was stable character of the clones, not subject to diurnal or seasonal variation, but was not a constant feature of the species as a whole. A survey of about 300 clones collected from different parts of India showed that while in the greater part of Central India the clones were devoid of starch, in the sub-Himalayan (terai) belt and in the eastern states of Assam, North-East Frontier Agency, West Bengal and Orissa, the predominant forms were the heavy-starch ones. In the peninsular portion south of Deccan and Orissa, the population was one of starch-less and medium-starch variants in more or less equal proportions, with a few high-starch forms scattered.

In the two northern tracts, the areas where the high-starch forms occur practically coincide with belts of more than 50 inches annual rainfall. In the peninsula, 12 out of 18 forms with heavy starch occur in montane or submontane areas. In Assam and Central India which are characterised by sharply contrasting rainfall conditions, the distribution is indicative of a high selection pressure. In some areas, where the conditions may be considered intermediate, a large number of medium-starch forms are seen. Their occurrence in other places side by side with high-starch and no-starch forms suggests that they might be continually arising through natural crossing between the high and no-starch ones, their persistence in nature being aided by vegetative propagation.

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In the absence of the author, Mr. R. R. Panje presented the following paper.

Paper

THE MORPHOLOGY OF THE GRASS SPIKELET WITH SPECIAL REFERENCE TO *SACCHARUM*

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INTRODUCTION

Studies of the morphology of the spikelet of *Saccharum* and related grasses previously reported by the writer (4), revealed various structures and evolutionary tendencies which could not be reconciled with prevailing interpretations. Particularly, the nature of the so-called sterile lemma and first glume of grasses of the Andropogoneae and Tripsaceae presented problems which could not be resolved by considering them as homologous with similarly named structures in other tribes of grasses. As a solution to these problems, it was suggested (4) that the so-called first glume of grasses in the sorghum and maize tribes is a modified prophyll (prophylletum), thus making the so-called sterile lemma of these grasses equivalent in position and homology with the second glume of other grasses such as those in the Paniceae. The reasons leading to this interpretation were not given and it is the object of this paper to present them so that a clearer understanding of the problems involved may be available.

TERMINOLOGY

When agrostologists use the word spikelet, they mean a very definite part of the inflorescence. As defined by Hitchcock (7, p. 992) a spikelet is "The unit of the inflorescence in grasses, consisting of two glumes and one or more florets". In the same book, Hitchcock, on page 8, notes that "A typical spikelet consists of a short axis (rachilla) on which the flowers are borne in the axils of two-ranked imbricate bracts. The spikelet is, therefore, a reduced modified shoot in which the rachilla is a stem bearing at each node a reduced leaf (bract). The flowers are secondary reduced shoots borne in the axils of the bracts, the first bract (palea) on the secondary shoot being a modified prophyllum......"

Bews (2) on page 6 refers to the spikelet as "the ultimate branch of the inflorescence" and on page 8 notes that "The most generalized form of the spikelet consists of an axis (the rachilla), bearing two sterile bracts at the base (the first and second glume, or lower and upper glumes), and an indefinite number of fertile bracts (flowering glumes, lemmas, valves, or inferior paleas), each with a flower in its axil."

An analysis of these quotations indicates that Hitchcock has defined a spikelet in two essentially different ways, as has Bews. They have both, in one manner, interpreted a spikelet to be a specific branch (rachilla) of the inflorescence with its appendages that has been modified more or less. In another manner, both of them have been very specific in defining a spikelet as consisting of a rachilla with two glumes and one or more florets. Furthermore, this latter definition is recognized by them as referring to the most generalized form of the spikelet from which other forms have been derived. No reference is made by either of them to the possibility that the rachilla may sometimes have a modified prophyll as its first appendage.

In this paper the more general concept of a spikelet as a rachilla with its appendages has been selected as the valid one because the author believes that a more primitive modification of the spikelet than the generalized form recognized by Hitchcock and Bews has been discovered. One of the most important objects of this Paper, therefore, is to show that such a more primitive and fundamental plan of the spikelet exists. It will be shown that the rachilla of certain grasses has an appendage below the glumes that is homologous not with the glumes but with a prophyll.

A prophyll (prophyllum) is defined by Jackson (9) as a bracteole (vorblatt). Jackson does not give an adequate definition of a bracteole but merely states, as the word implies, that it is a bractlet, or small bract at the base of an individual flower.

So far as grasses are concerned, the statement by Hitchcock (7, p. 7) on the prophyll is much more revealing. He states that "At the point where a branch shoot originates from a main shoot, (in the axil of a sheath) there is produced on the side next to the parent shoot a two-keeled organ (the first leaf of the shoot) called the prophyllum. At first the prophyllum completely covers the bud but later opens as the shoot develops. The organ is usually concave toward the parent shoot but clasps the new shoot by its margins." Converting Hitchcock's statement into a definition would result somewhat as follows : A grass prophyll is a two-keeled appendage found at the base of branches on the side next to the parent shoot.

Other technical terms found in this paper are used in the sense popularized by Hitchcock. The term rachilla, for example, is applied to the main axis of the spikelet and can be further recognized by the relation of flowers to the axils of some of the bracts that it bears. A discussion of the term lemma will be found in the latter part of this paper.

REVIEW OF LITERATURE

Only a few of the numerous publications dealing with the morphology of the grass spikelet will be referred to here. One of the first to study the grass inflorescence was Wydler (19). As translated by Frederick Grover, March, 1936, in U.S.D.A. Library, Wydler gives as one of his main principles the following : "12. All the branches of the inflorescence (with the exception of the terminal spikelets) are without developed subtending leaves (Mutterblatter) (Explanation e) and prophylla (Vorblatter) (Explanation f). Both should be considered as present in the primordium (Anlage), but as having failed of development." As part of explanation f he notes : "If we do not ignore the unity which is manifested in the structural plan of the grasses, we cannot deny prophylla to the inflorescence branches ; we must consider them to exist as their mother-leaves do, at least in their primordia."

Of classical interest to grass students are the conclusions of Hackel (5, 6), who made a careful study of the grass spikelet. According to him, the grass flower is without a perianth.

A report on the structure of the grass spikelet by Schuster (17) is of interest, because he believes that the lodicules represent true petals and that the palea represents the remaining two of originally three sepals. Janchen (10) likewise homologizes the palea with a portion of a calyx.

Of particular interest with respect to the structure of the spikelet of the Andropogoneae is the study of Johnson grass and Sudan grass by Long (13). She attempts to explain the nature of the so-called sterile lemma but is kept from attaining the solution presented in this paper by accepting (13, p. 158) the commonly held assumption that "The first two scales are very clearly the outer and inner glumes." This assumption is easy to make in the case of *Sorghum* because the vascular bundles of the first appendage of the spikelet of these grasses are so numerous as to obscure the prophyll-like nature of this organ.

McClure (14), referring to the confusion in the interpretation of the inflorescence in *Schizostachyum* (Bambuseae), notes in a footnote on page 544 that "It is probable that the neglect of the prophylls as constituting a category distinct from the bracts and glumes, and the consequent failure to use them as orienting structures, are largely responsible for this faulty interpretation." After such a penetrating analysis of the problem, it is unfortunate that McClure does not follow up this idea. McClure considers the spikelet to be a terminal structure.

Pilger (15), in considering the inflorescence and spikelets of *Guadua tessmannii* Pilger, begins, as translated by Grover : "It is well known that among the grasses the bracts and the prophylla of the branches of the inflorescence are usually wholly undeveloped." Pilger goes on to give a comprehensive picture of the development of an inflorescence of this species showing all branches as having bracts and prophylls.

It is desirable to indicate that Pilger (16) has also published a paper on the morphology of the grass spikelet. Pilger's interpretation of the Andropogoneae spikelet is at variance with that presented in this paper. He considers the first appendage of the Andropogoneae spikelet to be an empty glume but illustrates it two-keeled, as one would a palea or prophyll.

PRESENTATION OF EVIDENCE

Probably the most important reason why the first appendage of the spikelet of certain grasses may be homologous with a prophyll is the presence of structural repetition in plants. Since all vegetative branches of grasses have prophylls at their base, it seems reasonable to assume that branches of an inflorescence—if they are to be considered homologous with vegetative branches should also have, or, phylogenetically speaking, once have had, prophylls or prophyll-like structures at their base. The homologous nature of vegetative branches and branches of the inflorescence is indicated in that certain Bambuseae (*Schizostachyum lima, Guadua tessmannii*, and others) have prophyll-like appendages at the base of all branches of the inflorescence as well as of the vegetative axis.

Evidence for the statement that certain Bambuseae have prophyll-like appendages at the base of all branches of the inflorescence has already been presented by Pilger (15) and McClure (14). Since there is some confusion with respect to this point, it has been considered desirable to reproduce (Fig. 1) the illustration by McClure of an inflorescence of *Schizostachyum lima* (14, p. 545, Fig. 1).

No special survey was made of grasses of the Bambuseae in order to determine which genera have prophyll-like appendages at the base of their spikelets. It can be reported here, however, that such an organ was found in *Bambusa arundinaceae* Willd. and that it does not occur in *Arundinaria tecta* (Walt.) Muhl.

The presence of prophyll-like appendages at the base of all branches in certain Bambuseae is not particularly startling as this tribe of grasses has been considered to have the most primitive characteristics of all the tribes of

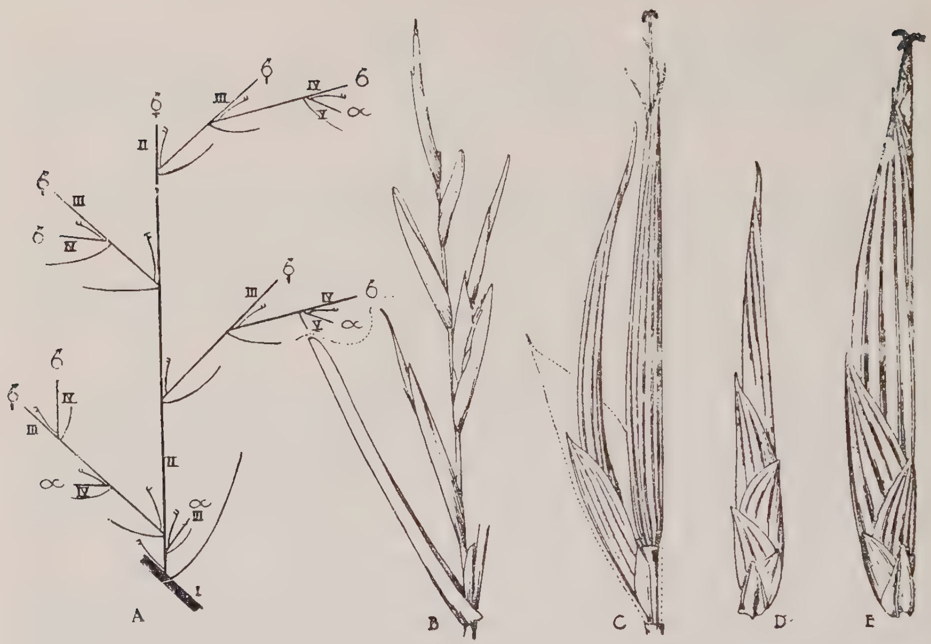

Figure 1.

From McClure (14, Figure 1) " *A*, Diagram of an inflorescence of *Schizostachyum lima* which may be taken as typical for the genus. The Roman numerals indicate the order of the rachis branches, counting the branch from which they originated, as I. ⚥ indicates fully developed perfect spikelets; ⚦ indicates rudimentary perfect spikelets; ♂ indicates staminate spikelets; ∝ indicates a bud or an incompletely developed branch. The bracts, and the sheath subtending the inflorescence, are indicated by simple curved lines, while the prophylls are shown as curved lines with two short lines inserted at right angles at their tips. *B*, A sketch of an inflorescence of *S. lima*. Some of the bracts, as well as the sheath subtending the inflorescence, have lost their pseudophylls. X 1. *C*, A portion of the tip of a rachis branch (pseudo-spikelet) of *S. lima* in an advanced stage of development. The lateral buds have produced branches which destroy its original spikelet-like appearance. The perfect spikelet (terminal) is supported by a short latera branch (another little pseudo-spikelet) terminated by a staminate spikelet. The subtending bract is indicated by broken lines. X 3. *D*, A small pseudo-spikelet of *S. hainanense* terminated by a staminate spikelet. X 5. *E*, A pseudo-spikelet of *S. hainanense* trerminated by a perfect spikelet. Note the 2-keeled prophyll at its base. Each of the four bracts bears in its axil a bud capable of developing into another pseudo-spikelet. X 5".

grasses by Bews (2), Hitchcock (8), and many others who have written on the phylogeny of grasses. Nevertheless, the great majority of grasses apparently are so highly modified as to be without prophyll-like structures at the base of all branches of the inflorescence except at the base of the flowers. The prophyll-like structure at the base of flowers is called a palea and has been recognized as a modified prophyll by Hitchcock (7, p. 8), Bews (2, pp. 5 and 8), and others.

The diagram in figure 1, *A*, is not complete in that it does not show the position of all the floral appendages. In order to clarify the position of additional floral appendages, an apical portion of diagram *A* is completed (Fig. 2)

It should be clear that Figure 2 illustrates the author's interpretation of diagram *A* in Figure 1 and not necessarily that of McClure. The construction of Figure 2, however, is based on statements by McClure, which indicate that the sign for hermaphrodite that he uses in diagram *A* represents a lemma and palea as well as the flower parts that are frequently meant by this sign.

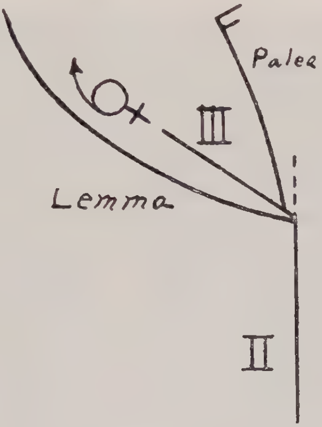

Figure 2.

Apical portion of diagram *A* in figure 1 as interpreted by the writer. ⚥ same as in figure 1, but minus the lemma and palea. The abortion of the apical portion of the axis marked II is indicated by the broken line. This axis is considered a rachilla by the author because it bears a lemma. The lemma illustrated would be the sixth glume (seventh appendage on axis II of Fig. 1, *A*) according to the terminology suggested in the latter part of this paper. An alternative name would be fourth lemma.

Although acceptance of this contention that all branches of certain Bambuseae have a prophyll-like appendage would make necessary a reinterpretation of the grass spikelet, an important objective of this paper is to show that certain grasses of the Andropogoneae and Tripsaceae likewise have a structure on their rachilla that is homologous with a prophyll. That certain grasses other than the Bambuseae may also have a prophyll-like structure at the base of the spikelet would depend upon their having retained it during their evolution from such an ancestor. With respect to the Andropogoneae and the Tripsaceae, this would mean that these tribes would have to be considered as having been derived directly from an ancestor which had this structure rather than from some tribe such as the Paniceae that did not have this structure. The author considers the evolution to have occurred in such a direct line, but it is desirable to note that Bews (2, p. 91) in his phylogenetic diagram derives the Andropogoneae from the Paniceae.

The evidence that indicates that the first appendage of the rachilla of spikelets of grasses of the Andropogoneae and Tripsaceae is homologous with a prophyll will now be presented. Undoubtedly, the most important evidence is the characteristically two-keeled nature of this appendage in many of the grasses of these tribes. This is particularly obvious in such of the grasses of these tribes as do not have very many vascular bundles in the structure (Fig. 3). A few of the genera that may particularly be mentioned in this respect are *Saccharum*, *Erianthus*, *Miscanthus*, *Miscanthidium*, *Sclerostachya*, *Andropogon*, *Arthraxon*, *Elyonurus*, *and Tripsacum*.

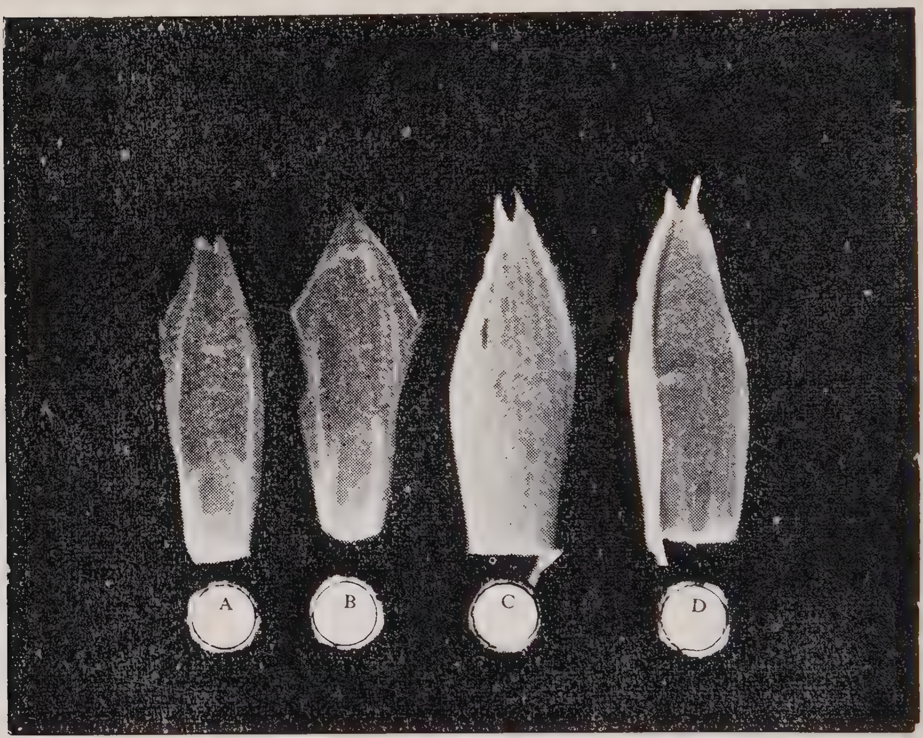

Figure 3. Front view (*A*) and back view (*B*) of a first appendage of the spikelet of *Saccharum spontaneum* L.; front view (*C*) and back view (*D*) of a first appendage of the spikelet of *Ischaemum latifolium* (Spreng) Kunth.

Genera such as *Sorghum* and *Zea*, which have numerous vascular bundles in the first appendage of their spikelets, do not always have this appendage two-keeled; nevertheless, there are signs that indicate that it is similar in nature. In these grasses, for example, there is no prominent midnerve or consistently odd number of nerves in spite of the well-developed nature of the structure. Often, two of the numerous nerves are more prominent than the others and are somewhat laterally placed. In the first appendage of the pedicellate spikelets of certain varieties of sorgo, such as "Leoti," "Indiana Amber," etc., there are not only two prominent nerves, but these nerves are further distinguished from the others by having a row of short spines where the keels normally would be.

The two-keeled nature of the first appendage of the spikelets of the Andropogoneae is clarified in many cases by the nervation of the appendage. An example of particular interest, because it illustrates the evolutionary steps in the development of a typically four-nerved appendage from a six-nerved one, is presented by *Erianthus maximus* Brongn. (Fig. 4). Similar stages, as well as additional ones culminating in a two-nerved appendage (nerves in keels), have also been observed in clones of *Saccharum officinarum* L.

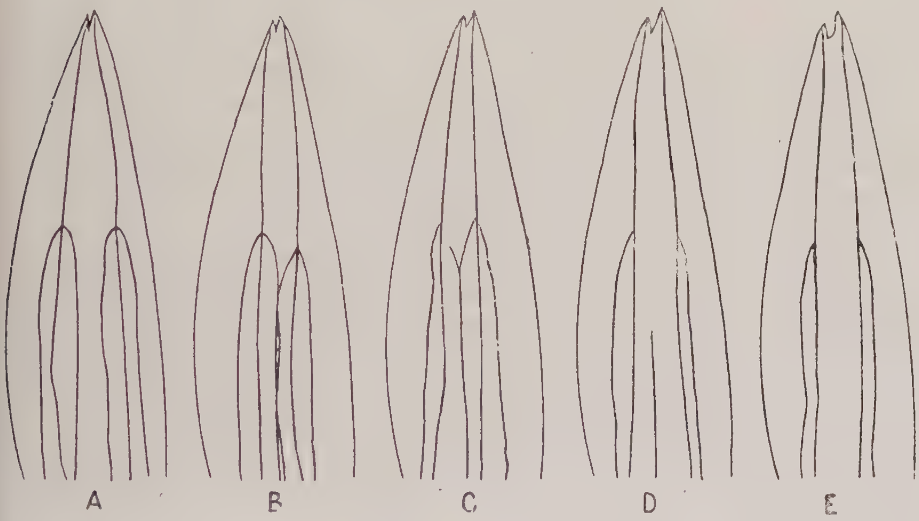

Fig. 4. Diagrammatic drawings of the first appendage of spikelets of *Erianthus maximus* flattened to show relation of nervation to keels. *E* is the typical from, the others being much less frequent. Actual size about 3 mm.

This bisymmetrical relation of secondary vascular bundles to the bundles in the keels is so different from what one would normally expect that some explanation of it must be given if the first appendage of the spikelets of the grasses in the Andropogoneae is to be understood. Those who believe that this appendage is homologous with a glume must explain how it may have two, four, six, or some other even number of nerves rather than the one, three, five, or other odd number normally present in succeeding appendages of the same grasses and in the glumes of other tribes of grasses. When, as here advocated, this appendage is considered homologous with a prophyll, no explanation of this particular symmetry is necessary as grass prophylls are bisymmetrical with respect to their two keels.

The distinct origin of the vascular bundles in the keels of the first appendage of the spikelets of *Saccharum* as shown by Artschwager, Brandes, and Starrett (1, Fig. 2, C) is additional evidence of the prophyll-like nature of this appendage.

The present attempt to show that the spikelet of certain grasses has a prophyll-like structure as its first appendage is complicated by the highly modified nature of the grasses involved. An appendage to be prophyll-like must not only be somewhat two-keeled, as shown in Figure 3, but must be the first appendage of a branch and on the side next to the parent shoot.

Evidence on these points was found in an apical part of an inflorescence of a cultivated *Saccharum.* The part was noticed because one of the rachis joints had three spikelets rather than the normal pair of spikelets attached to it. The fragment in question was different from normal only in that the pedicel, which normally bears the pedicellate spikelet, extended beyond a spikelet equivalent in position with what is customarily called the pedicellate spikelet and bore an additional spikelet a similar distance above it. The spikelets were normal. The feature of interest was that the spikelet lateral to the pedicel axis had its first appendage (two-keeled as normal) on the side next to the pedicel just as a normal prophyll has its back concave toward its parent shoot.

Other considerations also lead to the conclusion that a modified prophyll exists at the base of the rachilla of spikelets of grasses of the Andropogoneae and Tripsaceae. Those considerations based on the comparative morphology of other appendages of spikelets, such as the so-called sterile lemmas, are probably most significant. If it can be shown, for example, that the third appendage (the so-called sterile lemma) of these grasses is equivalent in position with the second glume (not the third glume, which is also called a sterile lemma) of the grasses of the Paniceae, then it will be apparent that the grasses of the sorghum and maize tribes have an appendage in their spikelets in addition to those found in the millet tribe.

Some reasons why the third appendage of the spikelet of the Andropogoneae* is equivalent in position to the second appendage (second glume) of such grasses of the Paniceae as do not have some of their glumes missing are as follows : A careful dissection, by means of binocular microscope, using about 20 magnifications, of literally thousands of spikelets primarily of numerous clones of *Saccharum*, as well as examples from *Sorghum*, *Erianthus*, and numerous related genera, has not resulted in the discovery of even one spikelet with rudimentary remnants of a flower truly in the axil of the third appendage. Whenever more than one flower was present, as frequently occurs, it was always what must be considered a second flower, or portion thereof, in the axil of a more or less rudimentary fifth appendage.

The relationship of extra flowers to the appendages is particularly clear in *Erianthus maximus* Brongn. In this species, in the one percent or so of apically placed spikelets with two florets, the fifth appendage in the axil of which the second flower is found is often so well developed that it can be seen with the naked eye to extend as an awn-tipped structure for a millimeter or more beyond the apex of the spikelet. Similarly, the relationship of a second flower to a fifth appendage in genera such as *Spodiopogon* (Andropogoneae), in which there are normally two florets per spikelet, is unmistakable.

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*Hereafter, whenever the word Andropogoneae is used in this paper, it is to be considered as meaning the Tripsaceae as well, as the differences between these grasses are not sufficiently significant to constitute a tribal difference.

Two-flowered spikelets of *Sorghum*, *Zea*, and *Saccharum* are difficult to dissect and interpret because of the very small size or absence of the upper appendages. In numerous wild and cultivated clones of *Saccharum* for example the reduction of even the fourth appendage (fertile lemma) is often so complete that many spikelets of a given inflorescence must be dissected before even a rudimentary one can be found (4,11). Obviously, the flower of such a spikelet cannot be considered as being in the axil of the second appendage just because the fourth appendage is absent. The fact that there are species of *Saccharum* in which the fourth appendage is absent or in process of being suppressed in advance of the palea and other parts of the flower in its axil is an indication of the order in which loss of appendages takes place within a spikelet. On this basis the fifth appendage subtending a second flower will also be suppressed in advance of the flower. Such a flower cannot be considered as being necessarily in the axil of the third appendage just because the fifth appendage is absent from a fraction or all of the spikelets of a given inflorescence examined. In making this statement, it is realized that Schuster (17), Weatherwax (18), Karper (12), and numerous others have apparently been misled by just such two-flowered spikelets into interpreting the spikelet of these grasses as sometimes or always having a flower in the axil of the third appendage.

The order of anthesis of two-flowered spikelets of the Andropogoneae is of particular interest in cases where the fifth appendage is suppressed or so small and scale-like as to be difficult to find or interpret. In such cases, *Zea* for example, it is the flower in the axil of the fourth appendage which flowers last and thus gives an indication of the true position of this flower with respect to the other flower. If the flower in the axil of the fourth appendage were the terminal one, it should flower first rather than last. This is an indication that the other flower is truly the terminal one and that it only appears to be the lower one because of the absence of the fifth appendage. There is no apparent reason why the evolutionary order of the suppression of parts in the spikelets of *Zea*, *Euchlaena*, *Sorghum*, etc. should be different from that of *Saccharum* and *Erianthus*, or that the order of flowering should be reversed.

The vascular system of the spikelet of *Sorghum* is carefully presented, but misinterpreted, by Long (13) is further evidence that when additional flowers occur they are above the flower in the axil of the fourth appendage. Her statement on page 162, "According to the plan of the glumes, where all bundles to one scale are attached below any of the bundles to a higher bract, x (rudimentary midrib of the third appendage) is in a normal position; but contrary to it y of the first flower appears above those of the second floret," (meaning by second floret the normal flower in the axil of the fourth appendage), indicates that she assumes rather than proves that there is a floret below the normal floret. Under the author's interpretation, the rudimentary bundle "*y*" is also in a normal position above the bundles of the normal floret, because it is a remnant of a second flower that so frequently occurs in *Sorghum* and related genera in the axil of a rudimentary or absent fifth appendage. Such spikelets with two florets (more rarely with a third flower in the axil of a sixth appendage) are generally found in the apical portions of an inflorescence.

The more complete development of the apical spikelets in many grasses is of considerable phylogenetic interest. The well-developed fifth appendage in *E. maximus* clone Riatea 1 at the apex of most rachises and its gradual decrease in size toward the base of the inflorescence is a good example of apical primitiveness. Another example is the relatively rare occurrence of spikelets with two florets instead of one in the apical portions of some vigorous inflorescences of *Saccharum officinarum* L.

The significance of the absence of a flower or rudimentary parts of a flower in the axil of the third appendage in the Andropogoneae is based on the fact that in the Paniceae the third appendage frequently has rudimentary parts of a flower in this axil. A glance through the generic descriptions in Hitchcock's (8) report on the genera of grasses of the United States reveals that numerous genera—*Anthaenantia*, *Leptoloma*, *Steaotaphrum*, *Eriochloa*, *Brachiaria*, *Panicum*, *Lasiacis*, *Sacciolepis*, *Oplismenus*, *Echinochloa*, and *Tricholaena*—of the Paniceae have a palea and sometimes also a staminate flower in the axil of the third appendage (sterile lemma of Hitchcock). This consistent difference between the third appendage of Andropogoneae spikelets and that of many Paniceae indicates that they are not as similar as, for example, the third appendage of Andropogoneae compared with the second one of Paniceae spikelets.

Further evidence that the third appendage of the spikelets of the Androgoneae is not equivalent in position to the third appendage in the Paniceae is presented by the presence of an awn on the third appendage of some Paniceae (*Oplismenus*, *Echinochloa* and *Tricholaena*) but never so far as is known on the third appendage in the Andropogoneae. This appears significant, because in the Andropogoneae when an awn is present, which is a common occurrence, it is on the fourth appendage and not the third. From the point of view of the comparative morphology of these appendages, it is apparent that the third appendage of Paniceae spikelets is more closely homologous with the fourth appendage of Andropogoneae spikelets than it is with the third.

Furthermore, it should be realized that the first appendage (first glume) in the spikelets of genera of the Paniceae is not two-keeled like the first appendage of the spikelets of numerous genera of Andropogoneae. Although all genera of Paniceae were not examined, a study of numerous examples did not reveal any genera in the classification by Chase (3) having a first appendage that might be called a modified prophyll.

It is interesting to note that much better and more numerous examples of genera with awned third glumes (lemmas) and without two-keeled first appendages in their spikelets might have been selected from the Festuceae, Hordeae, Aveneae, etc. The Paniceae were selected because of their supposedly close relationship to the Andropogoneae.

From the evidence presented it is apparent that the first appendage of the spikelets of Andropogoneae may be considered as homologous with a prophyll. Since this structure has a definite position in the inflorescence, it is desirable that it have a name. "Prophylletum" was suggested as the name for this appendage (4).

THEORETICAL CONSIDERATIONS

At this point, it may be desirable again to emphasize the fact that it is very likely that the great majority of grasses, except those referred to in this report as having a prophylletum (modified prophyll) on their rachilla, are so highly modified in this respect as not to have this structure. If only one species of grass had a prophylletum below the first glume, it still would be necessary to decide whether this structure was or was not to be considered a part of the spikelet and draw up a definition of a spikelet accordingly. Even if no existing species of grass had a prophylletum at the base of the branches bearing florets, it nevertheless would still be desirable to hypothesize about the absence of this structure when considering the general plan of the grass inflorescence.

No one can doubt the existence of a prophyll-like structure at the base of the rachilla of the spikelet of certain Bambuseae (*Schizostachyum lima*, *Guadua tessmannii*, etc.) unless he redefines the term " prophyll." This is true no matter which axis of the inflorescence of these grasses is designated as the rachilla, since all axes of these grasses have a prophyll-like structure at their base. Realizing this, the author has emphasized the interpretation of the grass spikelet with respect to the Andropogoneae, as his work is primarily with this group. Even if every argument presented with respect to the Andropogoneae were shown to be fallacious, the need for a new interpretation of the term spikelet would still be apparent.

Implications resulting from this interpretation of the grass spikelet need further clarification. An implication of particular significance is that the distant ancestors of all grasses which no longer have a prophylletum must have had such a structure. This should be especially realized when interpreting their present structure. A description of a highly modified spikelet cannot have very much significance if the manner in which the modification came about is not realized.

Another implication is that care should be taken when assigning numbers to the glumes. If, as has been contended, prophylleta are homologous with prophylls, and do not occur in the Paniceae, Festiceae, Hordeae, Aveneae, etc., then it must follow that the second appendages of spikelets of the Andropogoneae and such Bambuseae as have prophylleta are first glumes. It is apparent that comparisons of the spikelets of different grasses must be made from the same starting point and deal with homologous structures if they are to be significant. In other words, when comparing different grasses we must realize that certain genera (*Reimarochloa*, *Zizania*, *Zizaniopsis*, etc.) may have the prophylletum and first two glumes missing ; others (*Anthaenantia*, *Axonopus*, *Paspalum*, etc.) may have the prophylletum and first glume missing ; the great majority of grasses may have the glumes present but the prophylletum missing ; and that only a small proportion of grasses have the prophylletum present.

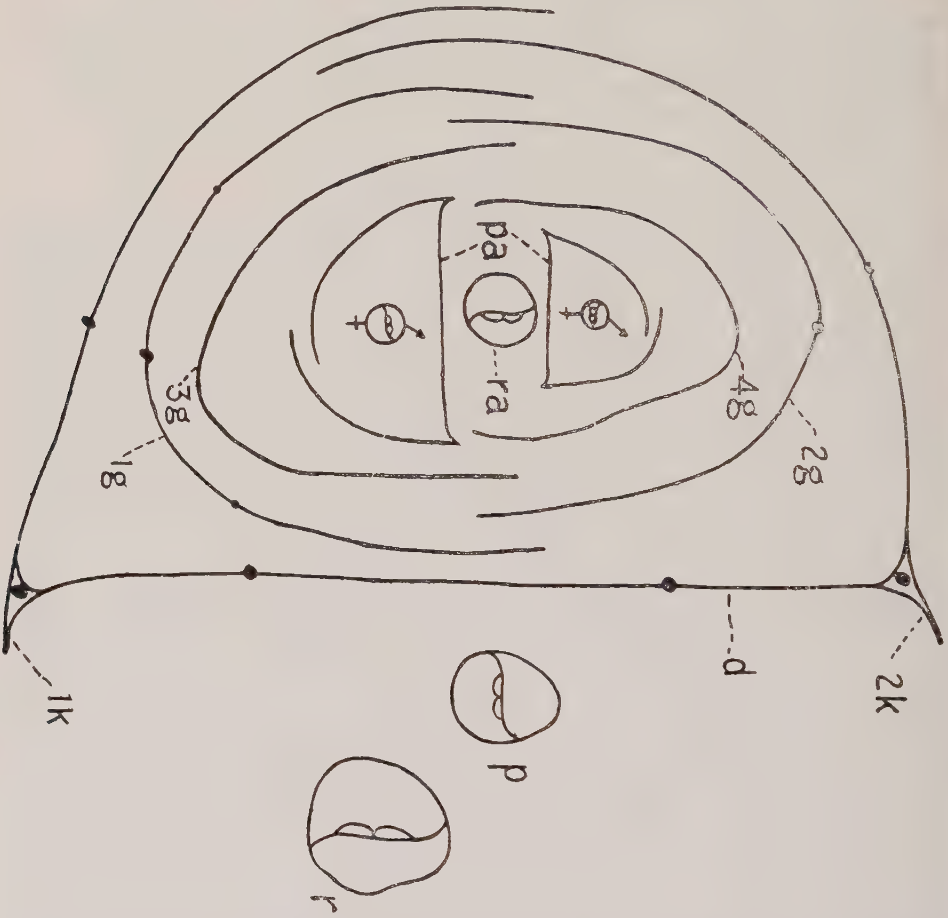

Fig. 5. Theoretical scheme of an Andropogoneae spikelet with two florets and subtending axes ; *r*, Rachis ; *p*, pedicel ; *d*, prophylletum (modified prophyll ; *1k* and *2k*, first and second keels ; *1g* to *4g*, first to fourth glumes ; *pa*, palea ; *ra*, rachilla.

On the basis of these conclusions, a diagram (Fig. 5) has been constructed to illustrate the theoretical nature of a spikelet of one of the Andropogoneae with two florets. The flower parts have not been shown, as they would merely complicate matters. Note particularly that the order of the appendages on the rachilla has been stressed by the overlapping of their margins. The face, or upper (adaxial) side, of the axes, has been indicated by a wavy line.

With respect to the terminology used, it should be noted that the term third glume is preferred to lemma, first lemma, or fertile lemma. The use of the word lemma, whether or not qualified, when considered from the point of view of the Gramineae (Poaceae) as a whole involves many objectionable features. A widely accepted definition of the term " lemma " as a " bract of the spikelet that normally contains a flower " illustrates the most objectionable feature of this term—the indefiniteness of its application. This indefiniteness has been rectified to some extent by interpreting " normally " very loosely. There is, for example, the tendency to use the misleading phrase " sterile lemma " when an appendage, homologous with the glumes but above the second glume in position, has or has not some rudimentary parts of a flower in its axil. Unfortunately, from the point of view of the logical use of the phrase, the presence or absence of rudimentary or other parts in the axil of any of the appendages of a rachilla is a relative matter, depending upon the species of grass involved. Under the circumstances, it is obvious that the use of such phrases as " fertile lemma," " sterile lemma," " palea inferior," etc., can have no significance so far as positional equivalence in distantly related grasses is concerned.

If the term " lemma " is defined as " The bract (or bracts) of a spikelet above the pair of glumes " (Hitchcock, 7, p. 990) and is always limited in its use to such appendages no matter whether they have or have not any structure in their axil, then the term lemma can have positional significance ; however, if this definition is accepted, it means that the term lemma could not be applied to either of the two glumes even in such cases in which either of them had a flower in its axil. Furthermore, it complicates matters in that it involves breaking up a homologous series of bracts into two differently named groups at an arbitrary point. The bract following the second glume would of necessity have to be called a first lemma when the position of the bract was in question.

The importance of having a terminology that permits the clear-cut recognition of positional equivalence cannot be overstressed. This is particularly true when structures as complex and specialized in various directions as some grass spikelets are to be compared. Without a recognition of positional equivalence, a phylogenetic arrangement of grasses would be impossible of attainment.

Returning to the analysis of the structure of a typical Andropogoneae spikelet, it is apparent that it is specialized in various ways. Specialization is here used in its phylogenetic sense as meaning deviation from a common ancestral form. It is noticeable, for example, that although the Andropogoneae spikelet form the morphological point of view is a lateral structure, it nevertheless has the appearance of being terminal because of the abortion of the pedicel axis, The same can be said of the uppermost floret, involving in this case the abortion of the rachilla axis.

As in most grasses, the specialization (primarily a reduction in the number of parts) which resulted in the present form of the Andropogoneae spikelet took place in two general directions ; that is, from the base and from the apex. The base of the spikelet is reduced in that the rachilla is greatly shortened and the axils of the lower appendages of the rachilla do not bear any structures as do the axils in the spikelet (pseudo-spikelet of McClure)** of some Bambuseae, such as *Schizostachyum lima*. The apex is likewise, but even more extremely, specialized in that evidence of suppression of appendages is everywhere present. The number of florets has, in general, been reduced to one or two, although additional ones are sometimes present. When two flowers are present, the fourth glume (fifth appendage) subtending the upper one is generally absent or greatly reduced in size. The variation in the shape and size of the third glume presents an interesting series culminating in its complete suppression in numerous clones of *Saccharum*. The palea has lost its keels and, in general, is so small and flimsy, if not completely absent, as to belie its true nature.

On the basis of the evolutionary trends illustrated by the Andropogoneae it is possible to predict the future changes in the morphology of the spikelet that may take place in this tribe of grasses. It would appear that the next step will involve the complete suppression of the third glume and the palea. Following this would come the reduction and final suppression of the second glume. The spikelet resulting would by itself be very hard to interpret and appear as if the lone flower were in the axil of the first glume.

The interpretation of a typical Andropogoneae spikelet given here (Fig. 5) makes it evident that this tribe can no longer be kept in the subfamily Panicatae (Panicoideae), as the main criterion separating the two subfamilies of grasses, " reduced florets, if any, above the perfect florets " (8, p. 5), now places the Andropogoneae in the Poatae (Festucoideae or Pooideae). Under the circumstances there seems no good reason why the division of the Gramineae (Poaceae) into two subfamilies, the Poatae and Panicatae, is desirable. The arbitrary division of the Gramineae into these two subfamilies is not a natural one, as there appear to be more than two main lines of evolution in this large family.

The evolutionary changes in the structure of the Andropogoneae spikelet discussed in such detail in this paper are in many respects not very extensive or remarkable. The evolutionary changes now taking place in the inflorescence of the Andropogoneae as illustrated by all degrees of suppression of the pedicellate

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**McClure (14) when referring to *Schizostachyum lima* uses the word spikelet as meaning what is here considered a terminally placed but morphologically lateral floret. When, as is advocated in this paper, a spikelet is defined as a rachilla (main axis of a spikelet) with its appendages, the difficulties experienced by McClure are mainly eliminated. When secondary and tertiary axes of the rachilla occur, there still remain, of course, the difficulty of conveniently and accurately referring to specific parts on them, spikelet (*Sorghum* and *Sorghastrum*) even to the suppression of the pedicel (*Cleistachne*) are much more striking. The evolutionary changes in the flowers, although not so drastic, have resulted in some fundamental changes of which the separation of the sex organs (*Zea*, *Sorghum*, etc.) is the most obvious.

When a comparison of the grass spikelet is extended to groups outside the grass family, a problem that has intrigued grass students for a long time comes to our attention. This problem is the homologies of the parts of a grass spikelet with the parts of a liliaceous inflorescence.

Concerning petals, it appears to the author that Schuster (17) is correct in homologizing lodicules with them. Schuster's belief that the palea represents the remaining two of originally three sepals is not so convincing. The author's belief that the palea is a modified prophyll makes it difficult for him to visualize that such a conservative structure is thus related to the sepals.

An explanation of the calyx which appears to be much more logical is that sepals are homologous with the first three glumes of the grass spikelet and that the palea and prophylletum have been eliminated by reduction from the liliaceous inflorescence. The change in the arrangement of the first three glumes from a distichous to a whorled condition and the straightening of the axes could be accounted for phylogenetically by crowding, resulting from a shortening of the rachilla.

CONCLUSION

(1) The grass spikelet is a terminally placed but morphologically lateral structure conveniently defined as a rachilla with its appendages.

(2) The first appendage of the rachilla of grasses of the Andropogoneae (including the Tripsaceae) and some Bambuseae is a modified prophyll, here called a prophylletum.

(3) The prophylletum is absent from the rachilla of grasses in the Paniceae, Festuceae, Hordeae, Aveneae, etc.

(4) The so-called sterile lemma of grasses of the Andropogoneae is a second glume, while the sterile lemma of the Paniceae is a third glume.

(5) The suggestion is advanced that the first three glumes of a grass spikelet are homologous with the sepals of a liliaceous flower.

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In the absence of the author the following paper was presented by Dr. H. M. Tysdal.

Paper

A LEAF SQUASH TECHNIQUE FOR STUDIES OF SOMATIC CHROMOSOMES IN *SACCHARUM*[1]

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The species of *Saccharum*, with their small and numerous chromosomes, are difficult subjects for cytological studies. The need for a suitable technique in preparing the somatic tissues of sugarcanes for cytological studies has long been recognized (Bremer 1931). Meiotic materials are not available for studies

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(1) Cytological investigations conducted as a cooperative project of the Hawaiian Sugar Planters' Association and the U. S. Department of Agriculture. Published with the approval of the Director as Paper No. 33 in the Journal Series of the Experiment Station, H. S. P. A., Honolulu, Hawaii.

in non-flowering varieties and may be obtained from other varieties only during the limited flowering season. Furthermore, it may be necessary, on occasion, to verify observations on meiosis with studies of somatic chromosomes. Paraffin preparations have been used to good advantage by numerous students of sugarcane cytology, but at best the method is a tedious one. Li and his co-workers (1954) have described a squash technique for root tips which, they report, has given satisfactory results. In this laboratory, however, all efforts to squash the root tips of sugarcanes have failed to yield adequate preparations.

Previous experience with other grasses prompted the author to try a leaf squash technique for *Saccharum*. After several pretreatments and fixing fluids were tried, a satisfactory schedule emerged. The method is described here in the hope that it will prove useful to other workers engaged in the difficult study of sugarcane cytology. This technique has been evolved by combining and modifying suggestions received from many persons. The search for excellent cells in preparations of somatic tissues is always time-consuming. The method presented below has given far better results with less expenditure of time than any other.

Meristematic leaf tissue is obtained from " seed " pieces which have been germinated between moist layers of newspaper in an incubator at 35°C. Under these conditions a burst of mitotic activity accompanies rapid germination. When germinating shoots are about 2 to 5 cm. long, they are cut from the seed pieces below the growing point, then split lengthwise through the growing point and placed in a cold aqueous colchicine solution. They are later transferred to Newcomer's fluid for fixation (6 parts isopropyl alcohol : 3 parts propionic acid : 1 part petroleum ether : 1 part acetone : 1 part dioxane—Newcomer 1952). If the materials are to be squashed within a few weeks, no further change of solution is needed for storage. If longer storage is intended, it may be well to follow Newcomer's recommendation that the fixative be replaced once after 12-24 hours with fresh fluid. In preparation for squashing, materials are transferred to a mixture of hydrochloric acid and Newcomer's fluid for hydrolysis. Following hydrolysis they are washed in water and transferred to 70% ethyl alcohol where they remain while squashing. A small piece of tissue is dissected out of the lowermost parts of the youngest leaves. This tissue is finely divided with dissecting needles in a drop of iron-aceto-carmine on a slide, a cover slip is put in place, the preparation is heated, and pressure is applied to the cover slip according to the usual methods of the squash technique. The schedule below is followed :

(1) 0.2% colchicine—2 hours, refrigerated
(2) Newcomer's fluid—24 hours or more, refrigerated
(3) 1 part N HCl : 1 part Newcomer's fluid—5 minutes at 55-60°C.
(4) Wash in water—1 or 2 minutes
(5) 70% ethyl alcohol—while smearing
(6) Squash in iron-aceto-carmine

Good preparations have been obtained by this method from a number of *Saccharum* varieties. Small adjustments in the length of time of hydrolysis are necessary for some varieties. The accompanying photomicrographs (Figures 1 and 2) illustrate the results that may be obtained by this technique. The two cells illustrated were exceptional in their clarity when studied under the microscope. They suffer somewhat in clarity through the limitations of photography and reproduction.

Observations are made on sealed or unsealed temporary squashes in this laboratory. It should be mentioned, however, that squashes prepared by the method described here are well suited to the modification of the alcohol vapour chamber method of making temporary preparations permanent without removing the cover slip (Bradley 1948).

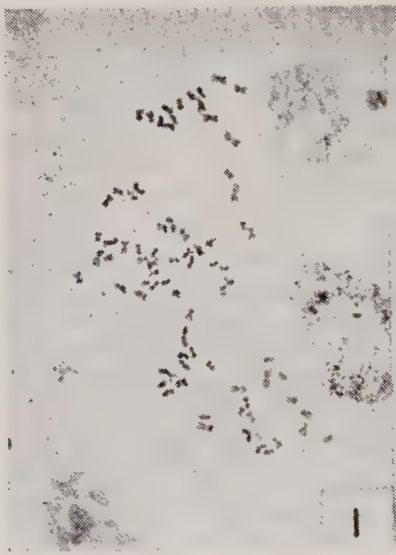

Fig. 1. Mitotic metaphase in leaf tissue of *Saccharum robustum*, clone 51 N. G. 140—Imp. 2006. 2n=80. About 960 X.

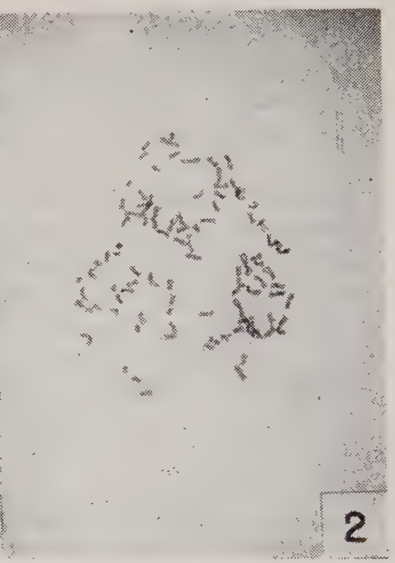

Fig. 2. Mitotic metaphase in leaf tissue of a wild(Fijian cane. Fiji No. 11—Imp. 2057. 2n=94. About 800 X.

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DISCUSSION

Mr. K. L. Khanna said that a Mycologist and Entomologist should have been associated with the spontaneum collection scheme. He congratulated Mr. Grassl on the valuable paper presented.

Dr. A. J. Mangelsdorf, on behalf of the Hawaiian Sugar Planters' Association acknowledged indebtedness to India on several counts. He explained that all the commercial varieties in Hawaii were derived from Co. 213. He stated that he looked to future help from India as regards supply of the newly collected clones of *S. spontaneum* for use in breeding.

At the suggestion of Mr. K. L. Khanna, it was decided that a sub-committe consisting of Dr. H.M. Tysdal, Dr. A.J. Mangelsdorf, Dr. S.J.P. Chilton, Mr. G. Mezery, Mr. N.L. Dutt and Mr. K. L. Khanna be appointed to prepare a brief report on the points raised and discussed at the cane breeding section and as to the future lines of work, to be presented at the second plenary session.

The Chairman thanked the delegates for their co-operation in the conduct of the session. After a vote of thanks to the Chair, the meeting was terminated.

ENTOMOLOGY SECTION

ENTOMOLOGY SECTION

Session-Saturday, 28th January, 11-15 A.M.

Dr. K. B. Lal, *Chairman*

The *Chairman* delivered the following opening address.

I am deeply conscious of the great honour done to me by the Central Organising Committee of the Ninth Congress of the International Society of Sugar Cane Technologists in asking me to act as the Head of the Sectional Committee of Entomology. Pests, particularly insect pests, constitute a major problem in the cultivation of the sugarcane crop and in most cases the yield at harvest and the quality of the sugarcane juice depends largely on the degree of the control of the pests achieved. Few crops are more liable to attack by pests than sugarcane, which may suffer from such attacks throughout the period of its germination, growth and maturity. In 1953 Harold E. Box of the Commonwealth Institute of Entomology listed 1398 species of insects and mites as feeding or occurring on sugarcane plant in different countries of the world. While the number of serious pests is undoubtedly much less, even this number may run into a few dozens.

It has been said that the more advanced the agriculture of a country or region is, the more complicated are the problems which its farmers have to face and overcome. In practically all sugarcane growing countries of the world, the cultivation of sugarcane may be said to have touched the highest mark of agricultural development so far achieved and it is, therefore, not surprising that in the choice and preparation of land, in the selection of seed, in the use of manures and fertilizers and implements ; in the provision of facilities for irrigation, in following a system of cultural practices and, last but not the least, in the control of pests and diseases, the sugarcane grower has undoubtedly to contend with a formidable array of problems. If he has managed to tackle these problems, even though with varying degrees of success, it is at once a credit to his ingenuity, resourcefulness and perseverance as well as to the agricultural scientists who have helped him to do so.

The papers received for presentation in this Section represent a good cross-section of the problems of pest control in the cultivation of sugarcane. Outstanding among them are the papers dealing with borers of various kinds and the methods of their control. Pyrilla, though very important in India is fortunately either absent or creates no problem in other sugarcane growing countries, in some of which it appears to have been replaced by such pests as thrips and frog-hoppers. Termites appear to be a serious problem largely in tropical countries, including India in so far as sugarcane growing is concerned.

The last decade has seen the gradual replacement of the older methods of control, based largely on mechanical and cultural operations, by newer methods, based on the use of chemical insecticides. This development has been helped by the evolution of various organic insecticides, specially those of the Chlorinated Hydro carbon group, and by the development of various types of hand and foot as well as power-operated machines for the dispersal of the insecticides on the crop. The insecticidal method has worked well in so far as such surface feeding pests as Pyrilla, termites and thrips have been concerned, but not so well yet against the internal agents of damage, namely, the borers. The old and somewhat pathetic belief in the value of the resistant varieties in the control of insect pests, has been disappearing, even though the literature on the subject of resistance has been accumulating. It cannot be denied that there are sugarcane varieties which are resistant to one pest or another but the overall employment of such varieties in the control of various pests has been far from impressive. Not only are the resistant varieties not resistant to all pests in a region but they also have a tendency to lose their resistance, if removed from the original areas of their selection or evolution. The variety Co. 421 in relation to its behaviour to the top shoot borer, *Scirpophaga, nivella* Fabr, is a good example of this kind of shifting resistance. In the realm of plant diseases, new strains of the red rot fungus, *Colletotrichum falcatum* attack with virulence the varieties which were originally evolved as resistant to this disease. This is what seems to have happened to Co. 453 in northern India. Above all, it is seldom that the resistant varieties combine various other desirable characters which the sugarcane grower must want. As an Entomologist, therefore, I have long lost faith in the efficacy of resistant varieties as a means of controlling pests. At any rate, this is our experience in India. This is, however, not to tell that sugarcane varieties should be released for cultivation without being tested for their behaviour towards insect pests and diseases, but that any great reliance placed on them in this regard would most likely lead to disappointment.

There is some parallel between the use of resistant varieties and the utilisation of the methods of biological control in dealing with the pest problems of sugarcane, although my faith in the latter method is unshaken yet. It is again undeniable that practically every insect pest of sugarcane, as of other crops, has its natural enemies which possibly or even probably keep down the populations of pests in certain areas and at certain times. However, it is one thing to have this phenomenon happening in nature and quite another to artificially harness it to our economic purposes. The mere collection and study of the natural enemies of a pest does not help us unless we are able to breed successfully and economically any of these enemies in large enough numbers, establish them over large areas and achieve a reasonable degree of control. The possibility of utilising *Trichogramma* against some borers has been under study in India since 1930 and in 1939, a well-planned attempt was made to liberate this parasite in many parts of the country for several years with a view to controlling the stem and root borers of sugarcane. The assessment of results in 1946 showed that except perhaps in two or three out of seven or eight areas, the parasite had not been successful. That question is still before us and the experience of other sugarcane growing countries has not been so uniformly indicative, one way or another, as to afford much definite guidance. In some areas of Uttar Pradesh, Pyrilla has been somewhat suddenly wiped out by the appearance of an ecto-parasite, *Epipyrops melanoleuca* in certain localities and at certain times but it has not been possible so far to employ this ecto-parasite artificially to any effective purpose. While studies on the biological and other methods of pest control continue, it appears to me that in the years to come, the sheer necessity of raising good sugarcane crops without taking much chances, would compel sugarcane growers to adopt increasingly the insecticidal methods of controlling sugarcane pests. Already indications are that some insecticides can be effectively employed even against sugarcane borers, though the operations would have to be carefully considered and well timed. It is in cases of this kind that the need for efficient plant protection services would be most felt and best utilised. Systems would have to be devised under which cultivators may be advised about the best times for spraying or dusting borers and means would have to be placed within the easy reach of cultivators for implementing such advice. This leads us to some practical aspects of plant protection into which I need not stray at this occasion.

I should like, however, to draw attention to an aspect of pest control which has always appeared to me very important but which so far has not received much attention. I refer to the need for assessing damage in terms of yield or cash value or both caused to the sugarcane crop by various pests and indeed also by diseases. If we must plan a rationalised system of plant protection measures, we must obviously know to what extent a crop is liable to damage by a pest or disease in any region. To what extent is infestation of a crop by a pest directly co-related with the degree of damage to it. We also need to evaluate the gains achieved as a result of pest control measures. What fraction of the cost of cultivation of sugarcane is being used up by plant protection measures and to what extent the crop can bear expenditure for this purpose. We hear so much about measures of pest control, being expensive or cheap, but in plant protection there is no absolute expensiveness or cheapness. All depends on what the crop is and how much economic burden as a result of pest and disease control, it can bear.

In the absence of the authors the following two papers were presented by Mr. Alfonso Gonzalez Gallardo and were discussed together.

Paper

VARIETAL SUSCEPTIBILITY IN SUGARCANE TO THE THRIPS *FULMEKIOLA SERRATA* (KOB.)

J.R. Williams

Entomologist, Department of Agriculture, Mauritius

Resistance, or conversely susceptibility, to thrips attack is known to be influenced by varietal characters in several plant species. Reference is made to Painter (1951) for some discussion of the subject and for bibliographies which include works on different varietal resistance to *Thrips tabaci* Lindl. in cotton, onions, tobacco, beans, and carnations, to *Selenothrips rubrocinetus* Giard. in cacao, to *Rhipiphorothrips cruentatus* Hood in grapevines, and to *Taenothrips simplex* Mor. in gladioli.

During the course of recent work in Mauritius concerning possible insect vectors of Chlorotic Streak Disease, observations indicated fairly clearly that one of the two main cane varieties at present, namely E. 1/37. was liable to suffer considerably from attacks of the thrips *Fulmekiola serrata* Kob. as compared with the other standard variety, M. 134/32. Further observations and enquiries confirmed the fact that the variety E. 1/37 was particularly liable to thrips injury and could be regarded as highly susceptible according to the terminology of Painter, i.e., it shows much more than the average damage done to other varieties in cultivation. Owing to the intrinsic interest of this observation for the economic importance of the thrips is normally believed to be slight, data were collected to supplement and substantiate this visual evidence of varietal susceptibility in sugarcane to thrips attack. These data are presented below, following notes upon the distribution and biology of the insect and the nature of the injury it causes to sugarcane.

THE SUGAR CANE THRIPS, FULMEKIOLA SERRATA (KOB.)

Distribution and food plants

F. serrata probably originates from the Oriental Region and is recorded upon sugarcane in Java (Van Deventner, 1906), Formosa (Priesner, 1934; Takahashi, 1936), and Mauritius (Moutia and Mamet, 1947). The author has also found it to be common upon sugarcane in Reunion Island and Madagascar during visits made to these countries in 1954. Although the first published record of the insect from Mauritius was in 1947, it is known to have been present for at least ten years before that date (coll. R. Mamet, 1937). There seems little doubt that it has been introduced into the Mascarene Islands and Madagascar with sugarcane plants from the Far East. It is the only species of thrips which is known to feed upon sugarcane in Mauritius and it has not been found on other plants in the island. Karny (1925) records *F. serrata* on tobacco in Java and this is apparently the only record of the insect upon a plant other than sugarcane.

Biology and nature of injury caused to sugarcane

The adults of *F. serrata* are small, slender, insects and their dark pigmentation enables them to be readily distinguished from the immature forms which are either whitish or yellowish in colour except for their dark red eyes. They crawl actively and leap occasionally when disturbed. The sexes were equally numerous during the period of these observations (August-December, 1953) when adults collected from cane shoots numbered a total and 1412 males and 1676 females. The females have the well developed ovipositor of the Terebrantia which is used to insert the eggs into the plant tissues. Eggs have only been found inserted into the upper surface of the leaf blades and they are always laid singly. Each is of an elongate reniform shape, approximately 0.29 mm long and 0.09 mm wide, with a smooth, shiny, translucent chorion devoid of surface markings. After deposition the egg is completely embedded in the leaf tissues except for one and which protrudes slightly through the puncture in the epidermis. It lies almost horizontally below the upper epidermis between and parallel to the vascular strands with its concave side uppermost. The exposed end of the egg is the anterior end and the dark eye-spots of the embryonic nymph are easily visible through the chorion.

The nymphs are colourless after emergence, except for the eyes, but they later become yellow. The yellow colour is deeper in the second stage nymphs, particularly when fully brown. The prepupae and pupae are pallid and have the usual features of these stages, that is, they are sluggish, do not feed, and may be distinguished by the short wing pads and forwardly directed antennae in the prepupal stage and by the long wing pads and backwardly deflected antennae in the pupal stage.

All stages of the life cycle may be found together in colonies on the foliage. The adults oviposit freely among the feeding scars and the subsequent stages are found grouped together. Pupation occurs *in situ* on the foliage, there being apparently no migration of the mature nymphs to the soil for pupation as often occurs in the Thysanoptera.

The colonies of thrips occur on the spindle in the shelter afforded by the partially unrolled leaf and distally along the margins of the youngest—or the two youngest—of the expanded leaves. Older leaves may show thrips injury but the insects themselves are almost invariably absent, there being a progressive movement of the thrips population, effected presumably by feeding or oviposition preferences of the adults, to the young leaves as they become available during growth of the shoots. On the expanded leaves, feeding occurs only on the upper surface and results in the upward and inward rolling of the leaf margins beginning from the leaf tips. The thrips live completely concealed within the rolled tissues and their continued feeding down the edges causes a progressive rolling and eventual drying down the leaf blade. It should be noted that the rolled tissue does not dry out for sometime, for the tight rolling prevents rapid water loss from the injured leaf surface and maintains an excessively humid microclimate in the cavity of the roll which is favourable for survival of the young stages. Within the crevice formed by the unrolling leaf of the spindle feeding occurs on both sides of the leaf which are, of course, in juxtaposition, but most of the feeding is nevertheless on the upper surface.

When thrips are numerous on young plant cane the leaves may become considerably distorted and dessicated over much of their length. A characteristic feature of heavy attack on such cane is seen in Plate I where the comparatively flexible leaves of the plant cane remain tied together at their tips owing to the twisting and death of their extremities before complete expansion of the leaf blade. Such injury is not known to adversely affect final growth although it is possible that it does so to some extent. Attacks are intensified in the greenhouse and may be troublesome, resulting in suppressed growth and sometimes in the death of young shoots. Thrips on fairly mature shoots and on the sturdy young shoots of ratoon cane never seem to cause such pronounced injury as they do on young plant cane. The effect of thrips attack of light intensity in the spindles of cane shoots is evident on expanded leaves as longitudinal striations of a paler colour than the rest of the leaf. These striations are easily recognisable as thrips damage by their rather indefinite margins and the speckling or non-uniform yellowness of the streaks themselves.

VARIETAL DIFFERENCE IN RESISTANCE TO ATTACK

As already stated, a susceptibility to thrips attack, characterised by frequent and often pronounced distortion and drying of the leaves, was observed in variety E. 1/37 and data was collected to substantiate this observation by comparing its liability to attack with that of the other chief variety in Mauritius, M. 134/32.

During Agust—December, 1953, fields of E. 1/37 and M. 134/32 were sampled to assess their respective degrees of thrips infestation. Four pairs of fields were chosen, each consisting of contiguous fields of mature E. 1/37 and M. 134/32. The degree of infestation by thrips was assessed in each field by selecting at random both mature stalks and young basal shoots from the whole of the field area and examining the foliage of each shoot for thrips infestation. A shoot was recorded as infested if immature stages were seen or if, in their absence, at least five adults were observed. This criterion of infestation was adopted to distinguish those shoots with casual visitors from those on which breeding occurred. The criterion is a reasonably good one for immature stages do not migrate from shoot to shoot, while the presence of several adults without visible young stages indicates that either they developed on the shoot or that oviposition into the shoot tissues is occurring. The results are shown in Figure 1, where each pair of fields is numbered 1 to 4 and where shoot infestation between varieties and between mature and young shoots of the same variety may be compared. It is evident from the data that the degree of shoot infestation was considerably and consistently higher in the fields of E. 1/37, while the younger shoots of both varieties were usually infested to a greater extent than the mature shoots.

The size of thrips colonies on infested shoots of each variety was then assessed. The technique used to extract the thrips from a shoot was to cut its spindle into short lengths and to immerse the pieces in 70% alcohol in 6″ by 1″ tubes. If any of the expanded leaves showed the rolled margins characteristic of thrips' injury, they also were cut and placed in the alcohol with the spindle pieces. The laborious procedure of extracting the thrips was then done at leisure by shredding the pieces with a needle and brushing them with a fine camel hair brush under alcohol.

Chiefly to facilitate the work of obtaining complete, or near-complete, extraction of the thrips, young plant cane 3-4 months old was used in order to

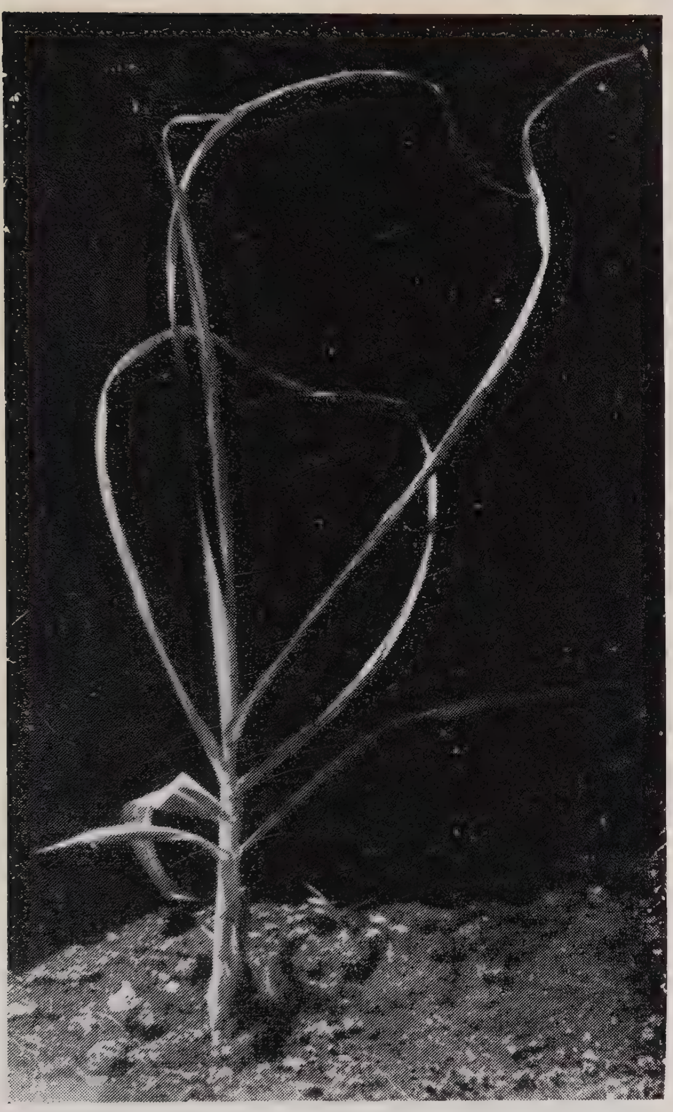

Plate 1 (a) Shoots of plant cane of var. E. 1/37 showing the effect of severe attack by the thrips *Fulmekiola serrata* Kob. Note the characteristic tying together of the leaves at their extremities owing to dessication before their expansion from the spindle.

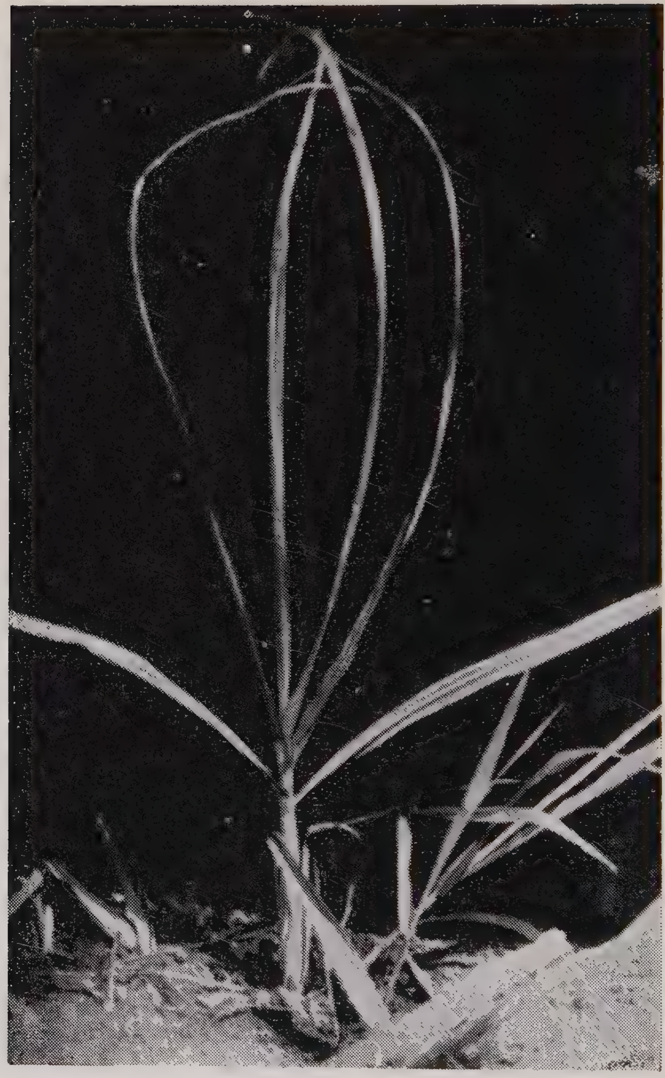

Plate 1 (b) Shoots of plant cane of var. E. 1/37 showing the effect of severe attack by the thrips *Fulmekiola serrata* Kob. Note the characteristic tying together of the leaves at their extremities owing to dessication before their expansion from the spindle.

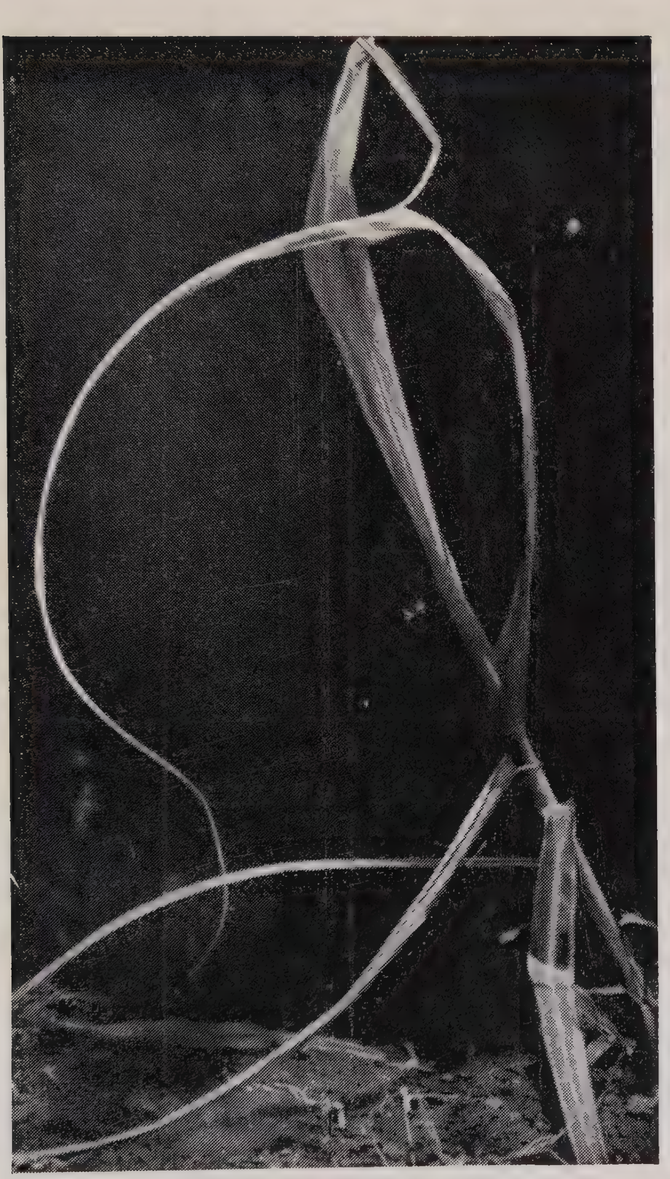

Plate 1 (c) Shoots of plant cane of var. E.1/37 showing the effect of severe attack by the thrips *Fulmekiola serrata* Kob. Note the characteristic tying together of the leaves at their extremities owing to dessication before their expansion from the spindle.

have only moderately sized shoots with small leaves. Young plant cane has shoots of various ages and sizes so only those of approximately one metre from base to longest leaf tip were taken.

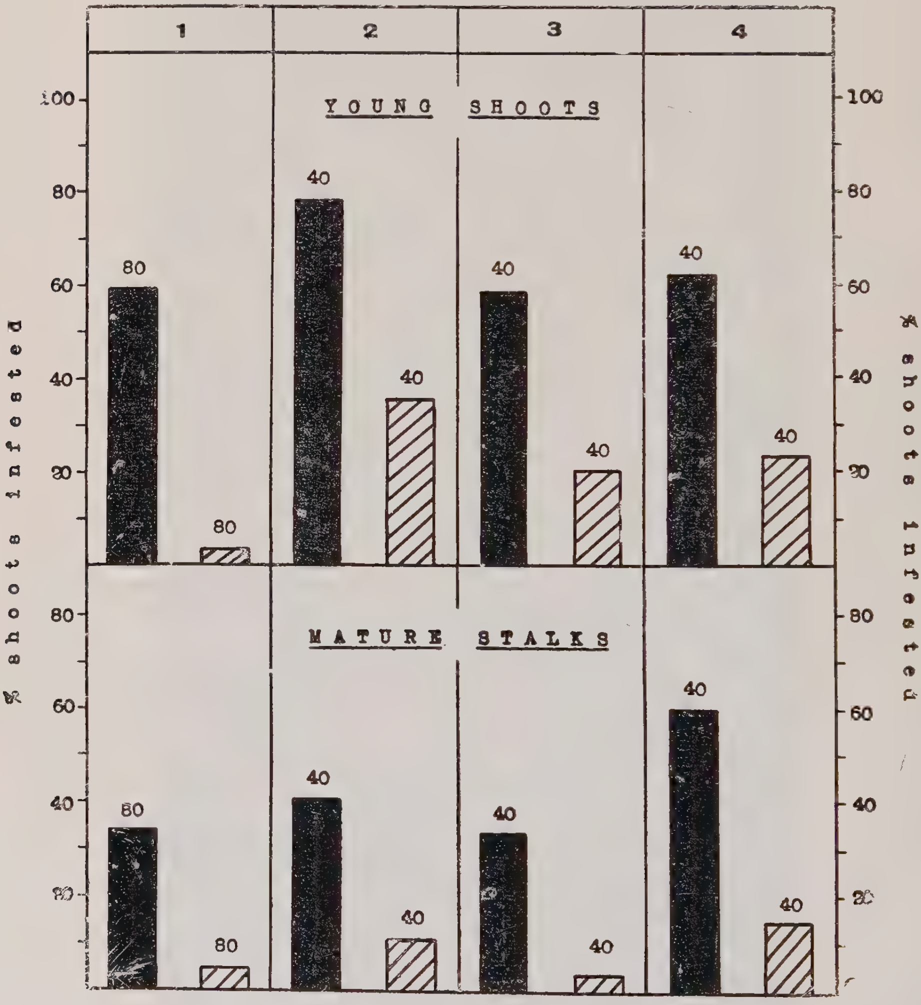

Figure 1. Infestation of sugarcane varieties by *F. serrata*. Shoot infestation in fields of mature cane. The number of shoots examined is indicated above each column. Black columns represent var. E. 1/37, shaded columns represent var. M. 134/32.

Three experiments were made ; they are summarised below while the data obtained from them is given in Table I.

TABLE I

INFESTATION OF SUGAR CANE VARIETIES BY *F. SERRATA* SHOOT INFESTATION AND SIZE OF COLONIES ON INFESTED SHOOTS OF YOUNG PLANT CANE

Experiment No.	1		2			3	
Cane Variety	M. 134/32	E.1/37	M. 134/32	E.1/37	B. 3337	M. 134/32	E.1/37
No. shoots examined	40	39	67	49	40	40	40
No. shoots infested	39	39	40	40	40	40	40
% shoots infested	97.5	100	59.7	81.6	100	100	100
Mean No. thrips per infested shoot	32.77	106.95	17.18	41.40	41.03	49.70	78.73
Standard deviation	27.03	64.18	21.28	47.50	21.29	25.85	28.25
Difference between means	74.18		24.22	8.67		29.03	
Statistical significance of difference	high		high	nil		high	

EXPERIMENT No. 1

Shoots were collected randomly in two adjoining fields of E. 1/37 and M. 134/32. The fields were of about 5 acres each and the cane in them both was of the same age.

The results showed virtually 100% shoot infestation in both fields, but the number of thrips per infested shoot averaged considerably higher in the field of E. 1/37.

EXPERIMENT No. 2

Shoots were collected at random in a field which contained alternating strips of the two varieties ; each strip was about 12 rows wide and extended across the field (about 200 yards).

Shoot infestation was higher with E.1/37 than with M. 134/32 and the number, of thrips per infested shoot was aslo greater.

EXPERIMENT No. 3

In a field of E. 1/37 where one row of M. 134/32 and also one of B. 3337 extended across the middle, shoots were taken randomly along the rows of the latter varieties and along one row of E. 1/37.

Shoot infestation was 100% with all varieties but the shoots of E. 1/37 bore the largest number of thrips.

It is concluded that more thrips are found upon variety E. 1/37 than upon M. 134/32 when both are growing under the same conditions and when their foliage is of the same age as shown by higher shoot infestation and the larger size of thrips colonies on infested shoots. The larger size of thrips colonies on infested shoots of E. 1/37 is evident even when the general level of thrips population is high enough to result in virtually 100% shoot infestation irrespective of variety. It is clear that varietal characters influence the size of the thrips population.

DISCUSSION

There is no evidence which suggests that variety E. 1/37 is more sensitive (less tolerant) to thrips injury than other varieties and its susceptibility is undoubtedly due entirely to the larger thrips populations which develop upon it. The greater number of thrips which it supports may be due to the greater attractiveness of the variety to the adult thrips or to varietal characters which are more favourable for the development and survival of the young stages. In the absence of experimental work it would be speculation to consider which of these mechanisms is operative in affecting the thrips population, or if both play some role. It is, however, of interest to note foliar characters of the two varieties which may be primarily responsible for their different resistance whatever the exact machanism of resistance may be. The foliage of variety E. 1/37 differs markedly from that of M. 134/32, and indeed from all the commoner varieties in Mauritius by its light green colour and its comparatively soft, flexible leaves. It is tentatively suggested that leaf texture is the influential varietal character and in support it is observed that thrips are more common on young shoots while extremely high, even complete, infestation of young shoots of plant cane seems common. The almost exclusive feeding on the upper leaf surface also seems a point in question for this surface is less cuticularised and has less skeletal and vascular tissues in its immediate proximity than has the lower surface. Furthermore, thrips are not found on the older leaves of shoots even in young plant cane. The picture which presents itself is of more thrips activity where foliage is tender, or more accurately, where plant structure offers less resistance to perforation.

SUMMARY

Fulmekiola serrata (Kob.) is a thrips which is extremely common and often very numerous on sugarcane in Mauritius although its economic importance does not appear to be great. It is also known to occur upon sugarcane in Formosa, Java, Madagascar, and Reunion. An account is given of its biology and the nature of the injury it causes to cane while data is presented to show the occurrence of varietal susceptibility. One of the two present main cane varieties in Mauritius is E. 1/37 which suffers pronounced leaf injury from attacks of the thrips as compared with the other main variety, M. 134/32. It is shown that the thrips population is

always greater on E. 1/37 than on M. 134/32 when both varieties occur together. The varietal characters which may be the primary cause of the higher thrips populations on E. 1/37 are briefly discusssed.

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Paper

BIOLOGICAL CONTROL OF *SIPHA FLAVA* F. BY MEANS OF *COLEOMEGILLA MACULATA* DEG. IN THE REGION OF CORDOBA VER MEXICO

SILVERIO FLORES CACERES AND ABEL RAMIREZ MARTINEZ
Oficina de Campos Experimentales Union Nacional de Productores de Azucar,
S. A. de C. V., Mexico D. F.

In April 1951 and July 1952, the Oficina de Campos Experimentales of the Union Nacional de Productores de Azucar, S. A. de C. V., hired the services of the Entomologist Dr. Harold E. Box, to make a survey of our main cane areas in order to establish a control programme against the borers and principal pests attacking sugarcane in Mexico. During the survey made by this scientist in the cane region of Cordoba, Ver., he pointed out the importance of the *Sipha flava* F. "Yellow Aphid" pest, and recommended its control by introducing from Mazatlan, Sin. the predator *Coleomegilla maculata* Deg. where this insect occurs abundantly.

According to this and with the purpose of implanting a biological control, we installed during 1953, an entomological laboratory at Cordoba, Ver. in order to start the artificial breeding of *Coleomegilla*, and for the last 20 months we have been studying the behaviour of the pest predators, hyperparasites and host plants, being many of these insects referred in their common names as they have been sent abroad for classification. The results obtained from the investigations made up to March 1955, are given below :

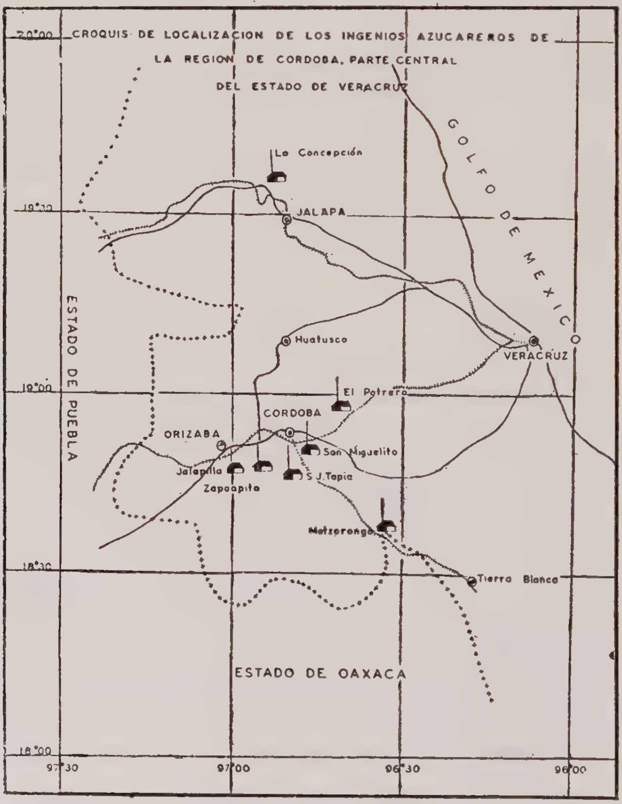
GENERAL DATA

During the last 5 years the pest of the yellow aphid has been increasing in the Cordoba sugarcane region, mainly in the cultivating fields of the Ingenios El

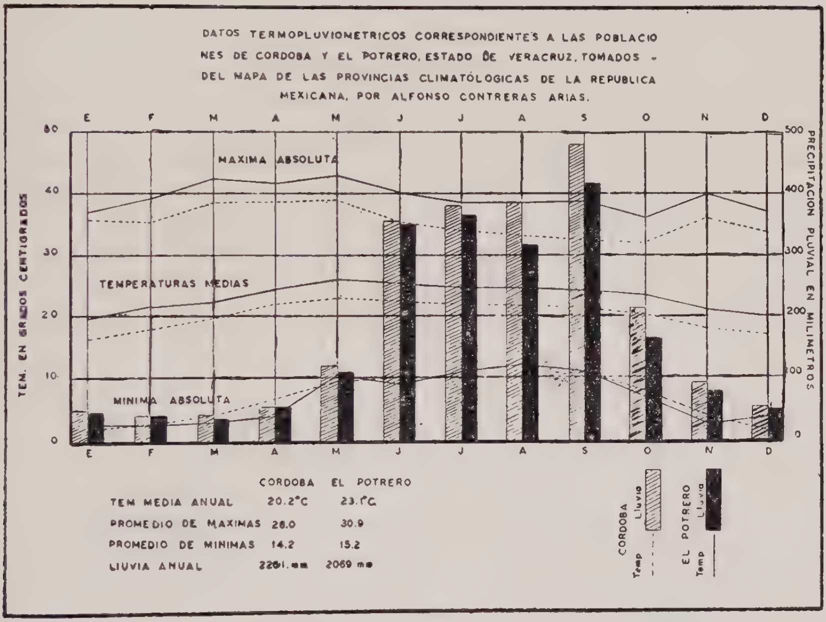
Potrero, San Miguelito, San Nicolas, San Francisco Toxpan, San Jose de Tapia, El Carmen, Zapoapita and Jalapilla, with an approximate total area of 20,000 hectares of cane, 75% of this surface corresponding to Coimbatore varieties (Co. 290 dominant) and the remaining 25% to Java varieties (P.O.J. 2878 and 2714).

In the surveys made in other cane regions, during the last three years, important damages have been found at the Ingenio La Concepcion, near the city of Jalapa ; Ingenio Central Tamazula, State of Jalisco and at Emiliano Zapata, State of Morelos, where the yellow aphid has been starting its attack on Co.290. Tamazula has an altitude of 1,235 mts. ; mean annual temperature of 22.5°C ; maximum average, 31.6° C ; minimum average, 13.5°C and annual precipitation of 981 mm. Emiliano Zapata has an altitude of 1,000 mts.; mean temperature of 24°C ; maximum average 32°C ; minimum average 15°C ; rainfall precipitation 940 mm. Cane cultivation is totally irrigated in both places.

The altitude of the cane fields extending from East to West in the region of Cordoba, from Potrero to Jalapilla, fluctuates between 500 and 1300 mts. being located in the vicinity of the cities of Cordoba, Fortin and Orizaba, exactly at the


CROQUIS DE LOCALIZACION DE LOS INGENIOS AZUCAREROS DE
LA REGION DE CORDOBA, PARTE CENTRAL
DEL ESTADO DE VERACRUZ
GOLFO DE MEXICO
La Concepción
JALAPA
Huatusco
VERACRUZ
El Potrero
CORDOBA
ORIZABA
San Miguelito
Jalapilla
Zapoapita
S. J. Tapia
Matzorongo
Tierra Blanca
ESTADO DE PUEBLA
ESTADO DE OAXACA
20°00
19°30
19°00
18°30
18°00
97°30
97°00
96°30
96°00

counterforts of the Sierra Madre Oriental and at an average distance of 120 kms. from the coast of the Gulf of Mexico ; the sugarmills of Providencia, Motzorongo and La Margarita, near the villages of Omealca and Tierra Blanca, to the southeast of Cordoba, have an altitude of 100 to 400 mts. According to the classification made by meteorologists Thornthwaite and Contreras Arias, the thermopluviometric balances of this region show that the climate is as follows : In the zone of Orizaba, SUPER-HUMID with almost null rainfall defficiency in the Spring and exceeding up to 120 cms. in Summer-Autumn ; TEMPERATE-WARM with uniform temperature regime. In Cordoba and Potrero, SUPER-HUMID and WARM with uniform temperature regime in three of the four seasons of the year. SEMI-DRY in Tierra Blanca, with rainfall defficiency from November to May. WARM, with uniform temperature regime. The zone of Jalapa has a very similar temperature to that of Cordoba.



DAMAGES CAUSED BY THE PEST

The damages of the aphis started to take importance in 1949 in the zone of Cordoba, exactly at the time when the varieties Rayada (Striped), Morada (Black Cheribon), Cristalina (Light Preanger), BH10 (12), SC 12/4 and others, had been withdrawn from commercial cultivation after being so cultivated for a long time. During the last 5 years almost only Coimbatore and Java varieties have been propagated and it has been possible to observe that the aphid's attack is much more severe in the Co. 290 and Co. 281 ; H-109 and H-37-1933 follow in an average degree ; the P.O.J. 2878 and P.O.J. 2714 are attacked only when they are intermingled with the former ones, but always at a lower rate. The starting infestation season begins from January to April, coinciding with the establishment of the dry season and when the cane is from 60 to 120 cm. high. The infestations reach their highest degrees from May to August and start to decrease from October to December ; however in a single field or lot of cane, the high infestation appears for only 60 or 80 days and when the attack is severe it dries nearly the 80% of the foliage. The aphid attacks the 40% of the cane stools as an average from May to August, and hundreds of living insects are liable to be found per young cane, that is, those ranging from 3 to 6 months old.

The damages caused by this suckling insect appear on the back side of the leaves, the higher ones being the more damaged, but at the time it increases in population, it starts to invade the heart's young leaves ; slight reddish spots appear in the damaged places and get assembled until they form an irregular spot of about 2 to 3 cm. taking a yellow-reddish colour later ; the leaves start to wilt and many plants die. A serious delay in the vegetative development takes place when these are capable of resisting. In the last 3 years we have observed the following : In 1952, which was a very rainy year, since the end of the Spring and during all the Summer, the aphid's infestations were very big. In 1953, it rained less than in 1952 and the infestations were also lower, however, in 1954, we had a precipitation similar to that of 1952 and the pest was stronger and proportionately higher than that of 1953. In order to be able to estimate the infestation degree we have established a comparison scale as follows :

Populations from 5 to 10 insects perinfested leave : Low Degree
,, ,, 11 to 25 ,, ,, ,, ,, Mean Degree
,, higher than 25 insects ,, ,, ,, High Degree

We have no precise data on the biological cycle of *S. flava* nor on the number of generations occurring in the six months during which the pest causes the highest damages, we have observed that they hibernate in the adult stage, thus spending the cold months until the season favourable to superposition arrives ; there is one or possibly two kinds of ants, not yet classified, that contribute greatly to the propagation of the aphis and protect them almost the year round.

Small surfaces are cultivated with corn interspaced with cane, being the habit to plant it when the cane starts to germinate ; this, and the Bermuda grass (*Cynodon dactylon*) are the two identified hosts ; however, there is an abundant population wild graminaceous growing near the cane plantations that might be considered as probable hosts ; Guinea grass (*Panicum maximum*) ; Para grass (*Panicum purpurascens*) ; Cutting grass (*Paspalum virgatum*) ; Camalote (*Paspalum fasciculatum*) ; slight patches of *Setaria poiretiana* Guatemala grass (*Tripsacum laxum*) and Job's tear (*Coix Lacryma-jobi*) appear in the hillsides, or more humid areas.

The yellow aphid appeared in a serious form at the zone of El Potrero in February 1951, in the young canes of Co. 290 and made it necessary for the factory's administration to proceed to control it with dustings of BHC 3% gamma isomer applied with hand pump at a rate of 25 kilos per hectare. A 100% control was observed in the fields where applications were made, but as only one uneven treatment was given for all the supply zone, it was observed a few weeks later that the pest continued to propagate and therefore it was not convenient to make the control of isolated areas. The writers accompanied Dr. Harold E. Box in July 1952, in a survey made by this scientist all over the region, verifying that the yellow aphid was propagating in a higher quantity and the damages were more intense than in former years. Dr. Box made attempts to localize the pest's native predators, but not a single specimen could be found. He recommended a search through the zones nearer to Cordoba, and to date we have only identified the *Cycloneda sanguinia* L. in very scarce populations.

WORK WITH COLEOMEGILLA MACULATA DEG.

This beneficial insect appears at El Roble (Mazatlan) near the Pacific Coast ; is very abundant in corn plantations but not so intense in canc. March-June are the months when it reaches its maximum population, being so great that one person, in an eight hour work, can collect with the hand and a vial tube, nearly 5000 specimens without using an entomological net. In no other part of the country have we been able to find such an abundant quantity, however, these insects suffer a strong hyperparasitism caused by several hymenopterous wasps and this represents a serious danger when being taken to a new zone, as more than a 25% of the population comes parasited. The most abundant hyperparasite has been classified by Dr. P.W. Oman as the species *Perilitus coccinellae* (Schrank), a wasp from the *Braconidae* family.

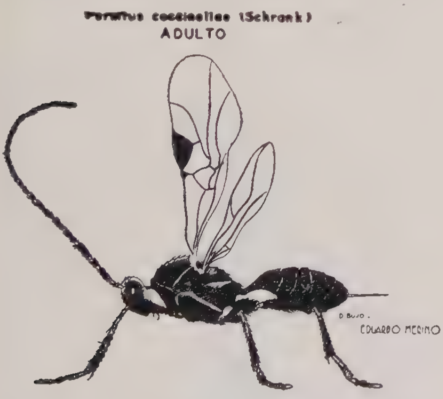


Fig. 1. Natural size from head to abdomen, 4 mm.

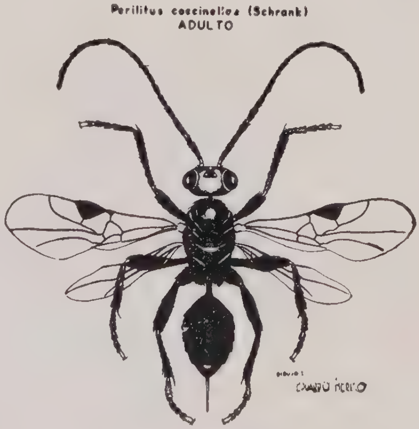


Fig. 2. Natural size from wing to wing, 7mm.

In March 1953, 18,000 specimens of *Coleomegilla* were collected at El Roble, and taken to Cordoba for the initiation of its artificial laboratory reproduction, but no success was achieved that year. The works were repeated with 38,000

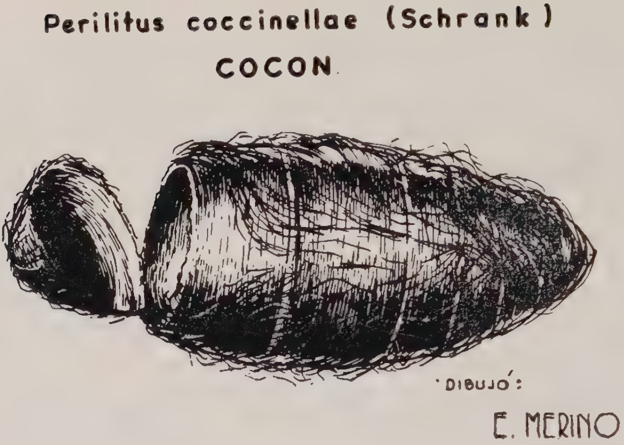


Fig. 3. Natural size, 5 mm.

specimens in May 1954, being able to master the breeding technique and obtain important data on the biological cycle, as with the initial material it is possible to breed up to 5 generations even in the cold months from November to January.

The *Coleomegilla* breeding technique was furnished us by Dr. W. Szumkowski, Chief of the Section of Biological Studies of the Agricultural Department of Maracay, Venezuela, and this interesting work was presented at the IX International Congress of Entomology, Amsterdam, Aug. 1951. The technique is based in feeding the adults with small pieces of beef liver, but as a very marked decrease appears in the number of eggs laid, as well as a high percentage of unhatched eggs or else an exaggerated mortality of larvae during the work, it is required to stimulate the reproduction capacity of the adults and the use of vitamin " E " in the adults and multivitamins in the small larvae. Aqueous solutions are prepared with these vitamins, where small pieces of beef liver are soaked in, taken out and fed to the insects three times a day, as they decompose easily. He also advises a great care with the larvae because of their cannibal habits, and to separate the eggs as soon as they are laid in order to avoid their being eaten. We started to follow this technique but discontinued it because of the occurrence of aphis in Cordoba during a great part of the year, therefore having no difficulties to feed the *Coleomegilla*. We are now using the following breeding technique :

We place the adult material coming from El Roble in canvas cages of 60 cm. high by 47 cm. in diameter selecting those hyperparasited ; this selection is made four or five times during two weeks until it is possible to separate the healthy ones which are placed by the hundred in smaller cages of 28 x 32 cm. the insects are placed in cages without sex control and at the time they become coupled, the couples are separated and deposited in numbers of 25 each into wide-mouthed glass flasks of 4 lts. capacity. The couple is caught during copulation and as this lasts several minutes, they can be easily caught with a test tube without harming them.

The adults are fed daily on fresh cane leaves infested by the aphid, cut with scissors into small pieces of 10 to 15 cm. for the tubes and from 25 to 35 for the cages. The females lay their eggs in groups ranging from 10 to 40 on these leaves. The first inspection is made every morning separating the last night's laying, making two or three more surveys during the day, since the eggs are liable to be eaten by the *Coleomegilla* if they are left in the tubes. When the eggs are deposited on the tube's walls, it is necessary to wait for them to acquire consistency using for the separation a little camel's hair brush and placing them finally on a piece of green cane leave ; sometimes a sheet of crumpled toilet paper is put within the tubes to absorb part of the moisture, but the insects lay their eggs on the folds. In such cases these are withdrawn by cutting the parts where they were laid putting them intovial tubes to wait for them to hatch ; this system of the paper avoids the risk appearing in cane leaves, which, the moment they start to wilt, roll their ends up imprisoning the eggs and spoiling and nullifying them.

The eggs are laid in more or less tidy rows and perfectly placed point-first, forming a right angle with the plane of the wall on which they rest. Yellow in colour which turns dark 24 hours before hatching ; ellyptical, of delicate consistency and measuring from 1.3 mm. in length by 0.6 mm. in thickness in their widest part. During the summer months they emerge from the third to the fourth day after the laying, with an effectivity of 95 to 100%.

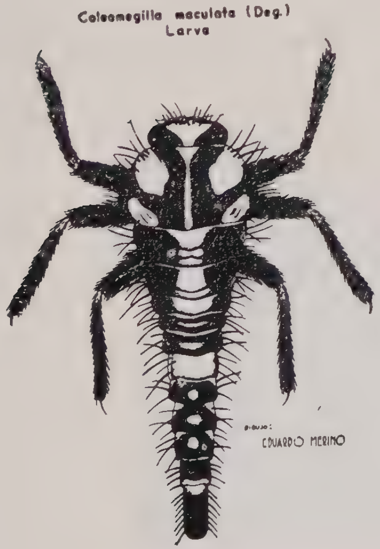


Fig. 4. Natural size approximately 6.5 mm.

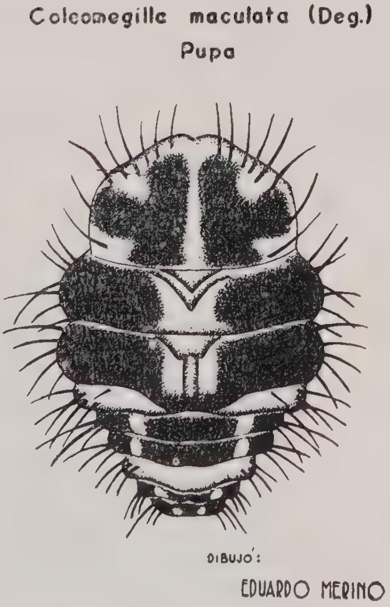


Fig. 5. Natural size approximately 5 mm.

When glass flasks are used for the couplings it is necessary to change and wash them three times a week as they are easily dirtied with the dejections, the walls are blurred and the debris accumulates in the bottom, which, with the water transpired by the cane leaves and the dead aphis, form residues where the living insects get stuck ; we do not use lamina caps in spite of the small pricks made on them, but pieces of cheesecloth which are fastened with thin rubber bands to the mouth of the tubes ; it is much more effective, much more ventilated and avoids the condensation of the water in the glass walls.

The larvae are black with yellow spots on the back. With three instarts taking 8 days during the summer ; first 2 days, second 2 days ; third 4 days. Immediately after they roll up and form a kind of little ball remaining in the pupal stage for 8 days ; the eggs take 4 days to hatch, 8 for the larval stage and 8 for the pupal, making a total of 20 days. During the cold months this period is extended to 35 days, proportionally lengthening the periods for the different stages; the birth effectivity decreases regularly in a 50% and in some cases, when the temperature is below 10°C, the egg masses dry up and do not hatch ; the mechanical wounds increase also at the moment of handling the dried and rolled up leaves, and this happens not only with the eggs but also with the larvae in which the last instar is considerably delayed ; the pupae requiring 8 days in the summer, take 20 in the winter. The insects brought from Mazatlan have lived up to 4 months (May-September) being properly fed, which shows that adults may be preserved alive in the laboratory a little longer.

Due to the larvae cannival habits it is necessary to place them individually into vial tubes of 20 x 70 mm. with their corresponding small piece of aphid infested fresh cane leaf since the day they are born; the leaves and the food are changed daily until the larva reaches its last instar ; at the initiation of the pupal stage they are placed separately and in clean tubes, without putting any food in them and

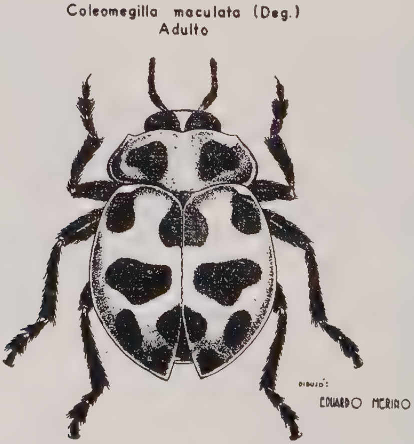


Fig. 6. Natural size approximately 7.2 mm.

as they become adults they are passed to 4 liters capacity glass flasks or into canvas cages where the multiplication is continued or else they are used for liberation in the field. The new couplings are made with these insects and it has been observed that they start to copulate four to six days after they become adults.

During the months of limited occurrence of the aphid, we have fed the insects with small pieces of fresh beef liver, by placing small slices on sheets of Bond or paraffin paper within the flasks ; they like this food but with the sudden change, a sudden stop in the layings is immediately noticed. We have also tried the ripe Roatan banana, well spread on the paper sheets which they eat pleasingly, but it has been observed that they lose capacity as predators. When layings are suspended a complementary diet based on vitamins " Roche " has been used, by dissolving one tablet in half a liter of water with which the leaves containing food are sprinkled ; the females taking these solutions start to oviposit from 24 to 36 hours after and the layings are made in the same proportion as in normal conditions. Only when this interruption is due to low temperatures prevailing from November to January, the stimulant effects of the vitamins are completely negative.

We have succeeded in mastering this technique and during the period June-December 1954, 5 complete generations of the insect were obtained in the month of May with initial lot of insects brought from Mazatlan. Apart from the considerable delay in the insect's biological cycle, no deaths were resented ; the breeding was continued without interruption and in March 1955, we had more than 6,000 winged insects bred in January and February of this year.

As to the habits of *Coleomegilla* it has been observed that the insects collected in the fields of El Roble are much more active especially during the noon hours, they have a fast though short flight. On the other hand, the insects bred in laboratory are very easy to handle and this is probably due to the fact that since their egg stage until they become adults they are kept in continuous captivity and little exposed to direct sunshine ; however, we do not think that the habits of these

Fig. 7. Liberations of *Coleomegilla maculata* in Co. 290 attacked by *Sipha flava F.*

last insects could undervalue the purpose to which they are devoted, that is the biological control of *Sipha flava*, as these are kept under a constant aphis diet since hatching.

INSECT LIBERATIONS

Liberations were made in 1954 as follows :

14,000 insects were liberated in June in two fields with 5 months old infested cane, 120 cm. high, variety Co. 290, distant 5 kilometers from each other ; these fields belong to the Hacienda La Concha of the Ingenio El Potrero.

10,000 specimens were liberated in August in the fields of Zongolica in two very infested cane fields distant some 500 m. from each other ; belonging to Ingenios Zapoapita and San Jose de Tapia, the cane being about 6 months old.

1,000 specimens were liberated in September in the zone of El Potrero in a field 8 kilometers far from those selected in July ; the aphid infestation was much lower and the cane fields were interspaced with corn.

Fig. 8. Cane plantations with interspaced corn. Both attacked by the yellow *aphid sipha flava* F.

During 20 days after the liberations and in each of the three cases referred, it was notable to find predators both in the places where liberations had been made as in those cane fields distant some kilometers ; however, no winged insects or eggs of larvae of *Coleomegilla* were found in further inspection made two or three months later. These liberations coincided with the rainy season which in 1954 was more intense than those of the last three years and unfortunately each liberation was followed by abundant rainfalls during the afternoon and night of the same day.

The aphid infestations have been low during the first three months of the present year, and we do not know how they will be during the Spring and the Winter.

Based on the above results we have planned the following programme for 1955 :

March.—The first 5,000 insects have been liberated to work against the first generations of aphis and as these last months have been dry, the present climatic conditions are favourable to their survival.

March-April.—Introduce from El Roble, the greatest possible number of *Coleomegilla* in their larval and egg stages in order to liberate them in the cane fields infested by aphis. We plan to liberate 20,000 insects in these biological stages. Up to April 5, 1955, more than 50,000 *Coleomegilla* in adult stage have been taken to the laboratory in Cordoba to be used as breeding base and have them reproduced during the year.

May-September.—Liberation of adult insects bred in laboratory, choosing those cane fields located at a maximum altitude of 500 m. as these are in the zone with the least precipitation of all the region.

June-December.— Increasing of commercial breeding of *Coleomegilla* until we are able to produce 100,000 specimens per 8 month season, appointing a 10% of the production for the Ingenio La Concepcion, near Jalapa and another 10% for the Ingenio Emiliano Zapata, State of Morelos, taking care of liberating the insects in the month of lower precipitation and in fields with less altitude over sea level.

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DISCUSSION

Dr. K. B. Lal enquired whether there was any relationship between the numbers of the predator beetles released and the crop areas which they were expected to cover. Mr. Gallardo replied that the number of beetles released in an area was not fixed as the idea was to first study whether the beetle got itself established under field conditions in Cordoba or not. Due to the abundance of rain following the releases of the predator beetle, its establishment in Cordoba could not be assessed definitely. However, the number of beetles in the colonised plots was sufficiently high.

In the absence of the authors the following paper was taken as read.

Paper

BIOLOGICAL CONTROL OF SUGARCANE STEM BORERS IN MYSORE ; A BRIEF REVIEW OF WORK DONE IN REGARD TO THE PRODUCTION AND LIBERATION OF *TRICHOGRAMMA EVANESCENS MINUTUM RILEY* IN MYSORE

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1. The Parasite Laboratory at Mandya in the Visweswaraya Canal Area in Mysore State was started in 1935 for the large-scale production and release of *Trichogramma evanescens minutum* Riley (Fam : Chalcidae) against the Sugarcane Stem Borer, *Chilotraea infuscatella*, Snell.
2. During the period of 20 years since the Laboratory was started, approximately 42, 64, 32, 750 parasites, mounted on 72,730½ cards were released on 30,722½ acres of young sugarcane crop.
3. A varying rate of increase in tonnage of cane harvested from colonised plots, compared to corresponding check plots has been recorded. This increase is not however entirely attributed to the effect of Parasite-release.

The Mysore Sugar Factory was started at Mandya in 1933 for the utilisation of sugarcane grown in the newly opened Visweswaraya Canal Tract (then known as the Irwin Canal Tract). The cane crop of the 1934 ' B ' season (July-November planting) having suffered a serious set-back due to stem borer attack, it was decided to establish an Entomological Laboratory at Mandya for the large-scale production of *Trichogramma evanescens minutum* Riley the natural egg-parasite of the sugarcane stem borer, preliminary investigations on the utilisation of this parasite for the biological control of sugarcane stem borer having already given encouraging results. This laboratory was also intended to take up investigation into and control of other sugarcane pests and other entomological problems in the area. The Parasite Laboratory began functioning early in 1935.

The Division of Entomology of the Mysore Department of Agriculture had taken up investigations on *T. evanescens minutum* in 1930, (1) under the direction of the late Dr. K. Kunhi Kannan, the then Entomologist. A suitable laboratory host for multiplying the parasite was found in the Rice or Flour moth *Corcyra cephalonica* Stn., since the eggs of *Sitotroga cerealella* (Paddy moth) used in other countries were too small in size. A simple technique for collecting host moth eggs, mounting them on small cardboard strips and exposing them to the parasite for ' stinging ' had been developed. Preliminary observations on the effect of small-scale liberations of parasites in sugarcane fields had been made. Thus the necessary technical data relating to the production of parasites and their field-releases was already available when the Parasite Laboratory was started. But this technique needed considerable modification in several respects in order to fulfill the purpose of the laboratory to produce sufficient parasite-material for large acreages of young cane. The necessary improvement in technique was evolved and the equipment for bulk-production of moths and Parasites installed by the end of 1935. The laboratory went into production early in 1936. The co-operation of Mysore Sugar Company authorities in providing funds and staff, and of the officers and personnel of the Farm section of the company in giving facilities for work and observations on Factory Farms has been available since the very inception of the Laboratory.

The various processes connected with the bulk-rearing of the host moth and the equipment needed for it have been described by Subramaniam (2) and Subramaniam and Seshagiri Rao (5), the technique employed for the mass-multiplication of the parasite and of the method of field-release of parasites by Subramaniam (2 and 3). These techniques were evolved in this laboratory for the first time in India. This work attracted the attention of the Biological Control Research Officer, of the (then) Imperial Agricultural Reasearch Institute, New Delhi, and the Entomologist in charge of the I.C.A.R. Scheme for research on sugarcane pests, at whose request, parasites for experimental releases in cane areas in Cuttack, and Lalseriya were supplied. Parasites were also despatched to Padegaon, Sitabgunj, Lyallpur, Ugar, Sagauli, Bellary, Walchandnagar, Seohara, Saharanpur, Chepauk, Bombay, Delhi, Ahmednagar, Muzaffarnagar, Kanpur and certain places within the state for field-releases, at the request of the concerned authorities. *Corcyra* eggs were also despatched to the following centres, outside Mysore : Indian Institute of Science, Bombay, T. D. O. Laboratories, Kanpur, Crop Protection Officer, Ahmedabad, Gola Gokarannath, Walchandnagar and Delhi. *Trichogramma* breeding stations were subsequently started in some of these centres mainly based on the technique developed in this laboratory.

PROGRESS OF WORK

During this period of 20 years in which the Biological Control of the sugarcane stem borer pest has been undertaken in the V. C. area, a total of 30,722½ acres of young sugarcane has been protected by this method. 72,730½ parasite cards representing an approximate population of 42,74,32,750 parasites have been utilised to colonise this acreage. The acreages of young cane in which *Trichogramma* was liberated, the number of parasite cards used and the approximate populations of parasites liberated, in successive years from 1934-35 to 1954-55 are given in the following Table I.

TABLE I

Year	Acreage			*Trichogramma* releases		Remarks
	Farms A-G	Cultivated fields A-G	Total A-G	No. of Parasite cards	Approx. No. of Parasites	
1934-35	12-00	—	12-00	—	2,75,000	Parasites reared on cardboard strips at Bangalore released.
1935-36	16-00	—	16-00	179	5,37,000	Approximately 3000 parasites per card.
1936-37	193-00	—	193-00	1292	38,76,500	
1937-38	630-00	—	630-00	3658	1,09,73,000	
1938-39	645-00	340-00	1005-00	3871	1,16,13,750	Includes parasites sent for 20 acres to North India.
1939-40	552-00	282-00	881-00	3294	98,81,000	Includes parasites for 47 acres despatched to North India.
1940-41	507-35	—	507-35	2078	62,32,500	
1941-42	1548-20	1548-00	3096-20	10,456	3,13,69,000	
1942-43	1560-10	1427-00	2987-10	9,455	2,83,65,500	
1943-44	1675-10	1580-00	3255-10	5858½	1,75,75,500	
1944-45	1985-00	1665-00	3650-00	1222½	3,66,07,500	
1945-46	688-05	122-00	810-05	4860	1,45,80,000	
1946-47	609-20	238-00	847-20	5085	1,52,55,000	
1947-48	56-30	6-00	62-30	376½	11,29,500	Owing to difficulty in getting Jowar for *Corcyra* rearing *Trichogramma*-rearing, received a set back.
1948-49	368-00	—	368-00	2208	66,24,000	
1949-50	32-20	—	32-20	192	5,76,000	do
1950-51	213-00	—	213-00	247½	59,36,000	
1951-52	736-00	—	736-00	552	1,32,54,000	From 1950-51, approximately 24,000 parasites produced on each card.
1952-53	536-25	2067-00	2603-25	1955	4,69,20,000	
1953-54	562-25	3045-00	3607-25	3185½	7,64,52,000	
1954-55	609-10	4598-10	5207-20	3725	8,94,00,000	
Total	13737-10	16918-15	30722-20	72730½	42,74,32,750	

(Note : A=acre G=gunta, i.e., 2.5 cents)

RESULTS OF PARASITE RELEASES

The effect of *Trichogramma* releases was studied in the early years of the establishment of the Parasite Laboratory by comparing (i) the percentage of egg-parasitism of *Chilotraea* egg masses collected at random from treated and control plots, and (ii) the tonnage of cane, per acre, harvested from colonised and check areas. There was a marked increase in the percentage of egg-parasitisation in treated plots ; initial parasitisations of 0.00 percent and 13.5 percent went upto 62% and 90%. As regards the yield, a varying rate of increase in tonnage of colonised areas (vide infra) was recorded (Table II), thereby showing that *Trichogramma* liberation had beneficial effect in lowering the incidence of the pest and consequently improving the yield.

TABLE II

CONSOLIDATED STATEMENT SHOWING THE TONNAGES OF SUGARCANE HARVESTED FROM COLONISED AND CONTROL PLOTS

Year	Season	Colonised Plots				Control Plots		
		Whether Cultivator's or Farm Cane	No. of Plots	Total area	Tonnage per acre	No. of Plots	Total area	Tonnage per acre
1933	—	Farm	1	1-00	16.9	1	1-00	10.2
1934	—	Farm	2	2-00	47.6	2	2-00	39.2
1935	—	Cultivator's & Farm	5	12-20	35.4	—	—	36.8
1936	B	Farm	16	29-34	34.7	4	19-01	26·5
1937	A	Farm	70	141-34	30.3	4	8-21	28.3
1937	B	Farm	131	289-30	32.7	....	....	....
1938	—	Cultivator's	23	106-10	30.4	18	59-16	27.9
1938	A	Farm	76	203-13	25.8	6	5-27	24.0
1938	B	Farm	126	383-00	35.0	5	18-35	34.5
1939	A	Farm	58	138-16	29.35	18	37-11	33.3
1939	A	Cultivator's	23	133-00	35.8	19	41-00	31.3
Releases outside V. C. area								
1937	A	Cuttack	1	1-00	26.23	1	1-00	19.08
1938	B	Babbur Farm	3	5-01	17.6	1	3-26	9.6

Although plots on a proper statistical basis could not be laid out to determine the relative efficacy of parasite release on yield, yield figures from suitably-located check plots were considered for comparison with tonnages from colonised plots. Detailed harvest data (shown in Table II in a condensed form) of some of the early years, were submitted for statistical analysis and extracts from the statistician's report on this material is given below :

(a) Report on harvest figures for 3 years from 1935.	In regard to 106 scattered areas " in 95% of the cases, the treated plots yield more than the control plots " (3)
(b) Report on 1938 data :	"........The average excess yield per acre for the treated over the control irrespective of the season of planting is 3.016 tons which is highly significant because this difference between the means could occur by chance in less than 5 cases out of 100. "

The improvement in the yield may be due to parasite-release, as well as other factors at work. But since the only material difference between the two sets of plots is the introduction of parasites into one, and withholding them from the other, it may perhaps be attributed to a large extent to this treatment.

In conclusion it may be stated that the results of *Trichogramma* release appear to have been satisfactory under Mysore conditions. Supplemented by other methods, e. g., the cultural method of light earthing-up (4), an effective control of the borer pest can be achieved here.

ACKNOWLEDGMENTS

It gives us great pleasure to acknowledge our indebtedness to the Mysore Sugar Co Ltd., and the Officers of the Farm Section for continued co-operation and assistance, to Messrs. T. V. Subramaniam and B. Krishnamurti Retd. Government Entomologists for guidance and encouragement, and to Mr. N. V. Naidu, Field Assistant and to the Laboratory and Field Staff at Mandya for their enthusiasm and hard work.

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Dr. R. M. Patel presented the following paper.

Paper

OBSERVATIONS ON THE CONTROL OF PYRILLA BY A PARASITIC FUNGUS (*METARRHIZIUM ANISOPLAE*)

R.M. Patel
Sugarcane Development Scheme, Ahmednagar, India

INTRODUCTION

In the Deccan Canal tract of the Bombay State, sugarcane suffers from several pests of which the serious one in recent years has been the Pyrilla. At present this pest is being controlled by chemical methods. Wagle, P. V. (1953) noticed the appearance of a parasitic fungus (identified as *Metarrhizium anisoplae*) on this insect. After carrying out some field observations, a note was published by the author (1954) to explain how far this parasitic fungus can be relied upon for the control of Pyrilla on a field scale. It was explained therein that the strong belief among sugarcane growers that the Pyrilla pest was immediately and automatically controlled by parasitic fungus needed careful scrutiny. It was also pointed out that there was no scientific proof yet available to show that the sudden disappearance of the Pyrilla pest as occurred during the monsoon months of 1953 in Shrirampur and Kopergaon talukas of Ahmednagar district in the Bombay State was due to the appearance of the fungus alone. Merely the presence of the fungus growth on the dead bodies of Pyrilla was not the sole proof that the pest died of the fungus attack. Since the fungus was not studied in any detail, no substantial information on its life history, the environmental conditions required for its multiplication in fields, its manner of attack etc., was available. It may be stated that there are many fungii which attack insects, but as they require special environmental conditions for their multiplication and which cannot be created in fields, the artificial cultivation and distribution of such fungii in fields has not been found practical.

Assuming that the fungus alone was responsible for the rapid disappearance of the pest in Ahmednagar district during the monsoon of 1953, attempts were made to multiply the fungus artificially in fields at a few places, and observations were made as to their success. Further, observations were also made on the working of the fungus appearing in nature with a view to knowing as to how far it could be effectively helpful to cane growers.

ARTIFICIAL MULTIPLICATION OF FUNGUS IN FIELDS

The strong rumour prevailing among cane growers that the fungus was released artificially in fields on the estates of certain sugar factories during 1953-54 and that the pest was controlled as a result of that work was entirely wrong. Attempts were, no doubt, made by one sugar factory to multiply the fungus artificially in laboratory (and not in fields) but with no success.

As it was found out that certain laboratory techniques employed for the cultivation of fungus were faulty in many respects, the Plant Pathologist to Government Bombay State, invited, during the monsoon of 1954 representatives from various sugar factories interested in the fungus, for training them in the cultivation of that parasite. Accordingly four factories got their representatives trained and attempted to cultivate the stock culture of the fungus which they obtained from the Plant Pathologist. The medium used and methods employed by them for the maintenance of the culture and the cultivation of the fungus on a large scale were the same as those given by the author (1954). The laboratory equipment essential for the purpose, especially autoclave, was procured by those factories. Flasks of 1000 ml. capacity containing the medium were inoculated with fungus culture. When the surface of the medium was completely covered by fungus growth, it was used for spraying after dilution with water. One flask was used for making one gallon of spray and such 10 gallons of spray were used to cover one acre.

The artificial release of fungus in the above way was carefully made on the estates of two factories, but the results obtained were not encouraging. After spraying the fungus, observations were made to see whether adults or nymphs of Pyrilla, either dead or alive, were showing any fungus growth on their bodies. For about 15 days, no sign of any fungus development in the fields that were sprayed with fungus culture was noticed. However adults of Pyrilla showing fungus growth appeared after a month, but by this time Pyrilla adults affected by fungus growth were noticeable everywhere, including fields which were not sprayed with fungus culture at all and which were located at a long distance from those treated with fungus. Thus it was not possible to conclude as to whether the development of fungus growth in fields after a month was the result of the spraying of fungus culture or due to the appearance of fungus in nature.

DIFFICULTIES OBSERVED IN THE WORKING OF THE FUNGUS APPEARING IN NATURE

So long as the artificial multiplication of the fungus is not successful, one has to depend on the fungus appearing and working in nature only. But there are two main difficulties observed in this respect also, which are discussed below :—

(i) Late appearance of the fungus in nature :—

It was observed during this year that the fungus appears in nature very late i.e. at the end of season when the damage to the crop has already been done by the pest. In both the areas in Shrirampur and Kopergaon the Pyrilla pest had appeared on a harmful scale from the beginning of June and the cane growers were waiting for the appearance of the fungus in nature in fields since then. The fungus did appear, but not at the time when the cane growers wanted it. It made its appearance as late as October i. e. after the Pyrilla pest had done enough damage to the cane crop.

(ii) Pest not rapidly controlled by the fungus as presumed :—

From the sudden and rapid disappearance of the pest in 1953 it was believed that once the fungus appeared in nature it was likely that it would kill the pest in a short time. This presumption was also found to be incorrect in the course of the observations during this year. On the estate of the Maharashtra Sugar Factory the attack of the pest was observed to have remained serious in a field even though the presence of the fungus was observed in the same field two months ago.

CONCLUSIONS

Attempts to multiply the fungus *Metarrhizium anisoplae*, artificially in fields in Bombay State have not been successful so far. Even when the fungus appears in nature there is no certainty that the pest would be effectively and quickly controlled because the fungus appears very late in nature and is not always capable of destroying the pest rapidly as is shown by past experience.

ACKNOWLEDGMENT

The writer wishes to express his grateful thanks to Dr. H. R. Arakeri, the Sugarcane Specialist, S.R.S., Padegaon, Bombay State under whose control these observations were made.

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DISCUSSION

Mr. S. N. Prasad stated that he had met with another species of fungus (a green muscardine fungus) which also killed Pyrilla at Motihari in Bihar. His attempts to culture the fungus in the laboratory did not succeed and, therefore, he wanted to know the media and the technique of culturing the fungus. Mr. Patel replied that no good medium had been found. The Chairman suggested that Mr. Prasad might obtain further information from the author directly.

In the absence of the authors the following paper was taken as read.

Paper

EFFECT OF INSECTICIDES APPLIED FOR CONTROL OF SOIL ARTHROPODS ON YIELDS OF SUGARCANE IN LOUISIANA, 1953-54

Ralph Mathes, L. J. Charpentier and W.E. Haley

Entomology Research Branch, Agricultural Research Service, United States Department of Agriculture[1]

Soil arthropods that attack sugarcane roots consist mostly of tiny symphilids, springtails, and bristletails. The most common ones found in the sugarcane fields of Louisiana are shown in Fig. 1. The symphilid *Hanseniella unguiculate* (Hansen) is the most abundant, followed by the springtail *Onychiurus armatus* (Tullberg), a bristletail *Japyx* sp., and the spring tail *Pseudosinella violenta* (Folsom). Although there are millions of these pests in an acre of sugarcane, they are seldom seen because they are so small and live underground. For these reasons their injury may wrongly be blamed on poor soil, unfavourable weather, or even the variety of sugarcane itself. Injury is most severe in heavy, poorly drained soils.

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[1] In cooperation with the Louisiana Agricultural Experiment Station.

These pests cause direct damage by gnawing into the sugarcane roots and cutting off root hairs. Indirect damage is caused by the wounds permitting an easy entrance for root-rotting organisms. Typical pitting of young sugarcane roots and the subsequent decay characteristic of initial stages of root disease are shown in Fig. 2.

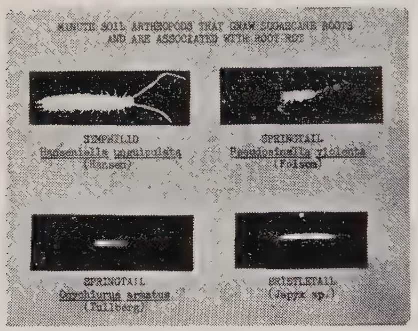
MINUTE SOIL ARTHROPODS THAT GNAW SUGARCANE ROOTS
AND ARE ASSOCIATED WITH ROOT ROT
SYMPHILID
Hanseniella unguiculata
(Hansen)
SPRINGTAIL
Pseudosinella violenta
(Folsom)
SPRINGTAIL
Onychiurus armatus
(Tullberg)
BRISTLETAIL
(Japyx sp.)

Fig. 1.

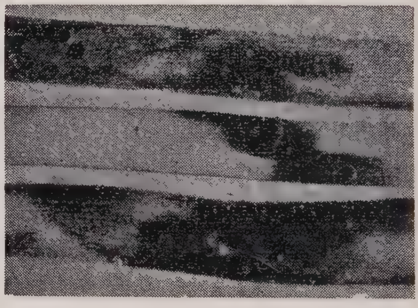

Fig. 2.

Chlordane, one of the new insecticides, had shown considerable promise in the control of these pests in small-plot experiments on heavy soil,[1] however, the sugarcane industry wanted to know if chlordane or other insecticides would be practical under large-scale plantation conditions and on other types of soils. In large plots the increased yield from treated plots are usually greater than in small plots, and the data are believed to be more reliable. In small plots arranged in checkerboard design many of the pests in the check plots probably migrate into the surrounding treated plots and are killed, whereas migration back into the check plots is much less because of the reduced population in the treated plots. Furthermore, insecticides may be washed into the check plots from treated plots nearby. After a heavy rain there is considerable movement of water up or down the rows, and the water may stand in the furrows up to the top of the ridges.

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[1] Soil Treatment with Chlordane Increases Yields of Sugarcane. By Ralph Mathes, J. W. Ingram, W.E. Haley, L.J. Charpentier, A.L. Dugas and E.J. Concienne, Sugar Bull. 31, No. 20, pp. 321-322, 1953.

In the fall of 1952 an experiment was set up to compare the effectiveness of insecticides on three plantations having different types of soil—sandy (Bon Secour), light (Shadyside), and heavy (Mc Leod). On each plantation there were usually 12 treatments and 5 replications in randomized blocks, covering about 35 acres. The fields were harvested in the fall of 1953. Each plot consisted of a strip of cane three rows wide and running the entire length of the field, which averaged about 600 feet. Untreated plots were between all treated plots. This made it possible to compare any treated plot with the untreated cane on either side.

The sugarcane was planted, treated, and harvested by plantation methods. The insecticides were applied in emulsions at the rate of 20 gallons per acre. Applications were made with a large 2, 4-D ground sprayer directly on the cane seed pieces in the open planting furrow just prior to covering with soil. The cane in each plot was weighed at the cane hoist or scale house and the yields were determined.

Table I gives a summary of the yield data for the three plantations. On heavy soil chlordane, endrin, toxaphene, isodrin, DDT and BHC increased the yield significantly over the checks, and dieldrin and parathion showed a trend toward increase. In the sandy soil aldrin caused a significant decrease in yield and dieldrin showed a trend in the same direction. No significant changes resulted from the applications to the light soil.

TABLE I

EFFECT OF INSECTICIDES TO CONTROL SMALL SOIL ARTHROPODS ON YIELD OF SUGARCANE

Insecticide	Pounds per acre	Increase or decrease in yield (tons per acre) Sandy Soil	Light Soil	Heavy Soil	Average
Endrin	1	+1.5	+1.0	+6.9	+3.1
Chlordane	5	+1.2	+0.4	+7.3	+3.0
Lindane	3	—	+2.2	+2.7	+2.5
Isodrin	1	+0.9	+1.6	+4.5	+2.3
Toxaphene	6	+0.8	+0.9	+5.3	+2.3
Parathion	3	+1.1	+1.3	+3.1	+1.8
DDT	6	+1.2	—0.5	+3.9	+1.5
BHC, gamma	2	—0.8	—0.3	+3.8	+0.9
Heptachlor	4	—1.5	—1.2	+2.3	—0.1
Fluorine analog of DDT	1	—	—0.3	—	—0.3
Dieldrin	4	—2.3	—2.5	+3.4	—0.5
Aldrin	4	—6.4	+0.3	—3.0	—3.0
LSD at 5-percent level		2.9	2.6	3.7	

The yields of untreated cane were 22.5 tons per acre on the sandy soil, 24.7 tons on the light soil, and 18.7 tons on the heavy soil.

As insecticides for control of soil arthropods have seldom increased cane yields in sandy and light soils, the experiment was continued only on heavy soil, with 10 treatments, in 1954. Table II gives the increases in cane yields for this experiment for the first and second year's crops in 1953 and 1954.

TABLE II

CANE YIELDS 1 AND 2 YEARS AFTER APPLICATIONS OF INSECTICIDES TO CONTROL SMALL SOIL ARTHROPODS IN SUGARCANE FIELDS ON HEAVY SOIL

Insecticide	Pounds per acre	Increase or decrease in yield (tons per acre) First year	Second year	Total
Chlordane	5	+7.3	+6.4	+13.7
Endrin	1	+6.9	+6.2	+13.1
Isodrin	1	+4.5	+4.5	+9.1
Dieldrin	4	+3.4	+5.6	+9.0
BHC, gamma	2	+3.8	+4.4	+8.2
Toxaphene	6	+5.3	+2.3	+7.6
Lindane	3	+2.7	+3.1	+5.8
DDT	6	+3.9	+1.5	+5.4
Heptachlor	4	+2.3	+2.1	+4.4
Aldrin	4	—3.0	+1.3	—1.7
Average	—	4.3	3.8	7.5
LSD at 5-percent level		3.7	5.2	

Significant increases resulted from chlordane, endrin and dieldrin in the second year. Both aldrin and dieldrin gave better yields the second year, indicating that these insecticides may have been applied at too high a dosage. Much more work remains to be done on rates of application. On heavy soil each of the five chlordane-treated plots outyielded the adjacent untreated plots. The lowest yield of these plots was higher than the highest of the untreated plots. Chlordane at 5 pounds per acre gave a total increase of 13.7 tons of cane per acre for the two crops. At $ 8 per ton this amounts to $109.60.

In conclusion it may be said that data from this large-plot experiment generally substantiated those previously obtained from small-plot tests. Chlordane again proved to be one of the best insecticides. Endrin was also very good. Both insecticides, as well as isodrin and dieldrin, substantially increased the yield in the second-year crop on heavy soil. Most of the insecticides gave a better performance on heavy soils than on either light or sandy soils.

DISCUSSION

Mr. Williams observed that although the paper related to the effect of insecticides on soil arthropods no data were presented as evidence of the reduction or death in the population of the soil arthropods as a result of the insecticidal treatments.

In the absence of the authors the following paper was presented by Mr. Alfonso Gonzalez Gallardo.

Paper

THE BIOLOGY AND CONTROL OF AENEOLAMIA POSTICA (WLK.)

Jose V. Hernandez O. and Silverio Flores C.
Campos Experimentales—Union Nacional de Productores de Azucar,
Mexico, D. F.

INTRODUCTION

The Mexican sugar industry has suffered considerable decreases in the field yields during the last decade due to the attack of an insect known by the Mexican farmers as "Salivazo". "Chicharrita", "Mosca Pinta", and "Mosca Coralilla", which actually are different varieties of Homoptera of the *Cercopidae* family. The most important one has been identified as *Aeneolamia* (*Tomaspis*) *postica* (Wlk.).

Among the most important reports on damage caused to the Mexican sugar factories we have :

1943. Appearance in plantations of Ingenio Cuatotolapan, Ver. in variety P.O.J. 36, applying for control to Dr. J. Matts' recommendations.

1949. Severe damages in second ratoons of P.O.J. 2878 at the Walamo's Sin. Piloncillo mill.

1950. *Aeneolamia postica campecheana*, subsp. n. Fennah, reported attacking in a severe form, more than 200 hectares of the Ingenio La Joya, Camp. Good control achieved by means of BHC, DDT and Sulphur.

1951. Damages were very extended and intense at the Ingenio Costa Rica and it was necessary to burn the infested fields. Due to drought and the combined attack of *Diatraea considerata*, Heinr., the cane was weakened in such a way that losses were higher than those suffered in other regions. The insecticide that proved best was 3-10-40 (BHC-DDT and Sulphur) dusted by plane.

1952. It widely attacked ratoons of P.O.J. 2878 at El Mante and Xicotencatl, Tamps. Dr. Blackburn recommended the use of 1% BHC and 80 mesh limestone for the nymph, applied around the stools and in the soil around the stools, at a rate of 100 to 200 K/Ha.

1953. More than 150 hectares of creole cane and P.O.J. 2878 were attacked at the El Higo, Ver. sugar mill. It was fought with 3% BHC at a rate of 30 kilos per hectare sprayed by plane. It appeared also at the Ingenio de Nueva Zelandia, Tab., attacking intensely 50 hectares of second ratoons of P.O.J. 2878. Also at Cuatotolapan, Ver., La Joya, Camp. (where it occurs with more or less intensity each year) and in a two hectare field of the Ingenio El Potrero, Ver. in P.O.J. 2714.

The results of investigations held in two Mexican cane regions—Costa Rica, Sin. and El Mante, Tamps. on *A. postica* (Wlk.) the most injurious species—are being referred to in this paper also.

INSECT'S BIOLOGY

(a) *Ecology.* Works consulted include numerous details in this respect starting from its origin (wild graminaceous), its gradual passing to sugarcane favoured by clearings and intensive cultivation, its occurrence and abundance in grassy plains and swampy fields, in artificially introduced graminae and in the woods with high precipitations, inferring that the natural or semi-natural pastures do not constitute the insect's original habitat. It is therefore concluded that *T. saccharina* (important in Trinidad) comes from the damp woods and not from the pastures.

Wild graminaceous plants are quoted also among the main hosts of this important pest.

The different species and sub-species that, according to Dr. Harold E. Box (1953), represent the genera *Aeneolamia* and *Prosapia* from the zones between San Cristobal, Ver. and Monterrey, N. L. in the Gulf's region and between Chilpancingo, Gro. and Guliacan, Sin. in the Pacific's watershed, as well as in numerous places of the country's central cane areas, have not yet been identified for Mexico. R. G. Fennah (1950), identified the *Aeneolamia postica campecheana*, subsp. n., for the Yucatan Peninsula.

As to host plants (main host), only *Paspalum* sp. of the Paniceae subfamily, growing near the canefields, is known as the insect's reservoir.

As stated by Dr. Harold E. Box, *there are enough proofs to assure that Aeneolamia starts to adapt itself to live in cane in a way similar to that of the cane areas of Venezuela during recent years.*

(b) *Biological Cycle* : *Copulation or Mating* : *Aeneolamia's* copulation or mating is effected 48 hours after ecdysis (in Laboratory), but under field conditions it generally happens sometime later.

As the proportion male-female varies under field conditions it was thought that each female could be fecundated more than once, because of the high percentage of males. Experiments were made by placing in cages an equal number of males and females. Separately were placed a six times larger number of males than females. Care was taken in selecting the best developed insects and that the males were, in any case, 24 hours older than he females. Insects taken at random, without selection either in number or age, were used as checks.

Daily observations showed :

1. No double mating for the same female was noticed either from the fecundating male or any other.
2. Unmated females did not lay fertile eggs during the days before their death ; however, those of the same data and whose copulation had been observed, did so.

3. It was observed that, while attempting copulation, the males make a selection among the females in a lot. De Long (1938) states that experiments made with *Empoasca fabae* (Harr.) different matings with different males achieved under special conditions, do not affect the total number of eggs.

It is thought that mating is liable to take place more than once in the case of *Aeneolamia* when specimens of both sexes live together 24 hours a day, as during the experiments made, insects of both sexes were kept together for only 10 hours.

Unmated females show a greater incompatibility with regard to selection, which from our point of view, goes in accordance to size and maturity.

For best results it is advisable to form couples with 72 hours old males and 48 hours old females. In all cases the mating gives the logical result in fertile eggs.

If the male and the female are of the same age, they are not sexually attracted until 72 hours after ecdysis. When the male is 24 hours older than the female, mating takes place only when the female is 48 hours old ; if the male is 24 hours younger than the female, the mating, if any, takes place between the 72 and 96 hours.

In each case the couple was placed in the observation cage for the period above described, and when no response was obtained, they wre separated into individual cages repeating the operation the following day until achieving the results described.

As all the insects, the males have their prenuptial dance which lasts, according to their maturity, from a few minutes to several hours, with resting periods in this case.

The duration of the mating or copulation ranges from 15 to 75 minutes according to cases observed and referred to in Table I.

TABLE I

MATING OF *AENEOLAMIA POSTICA* (1953-54) ENTOMOLOGICAL LABORATORIES OF COSTA RICA, SIN. AND EL MANTE, TAMPS

Num. cases observed	Period in minutes Minimum	Maximum	Average
25	15	75	50

Preoviposition. Table II shows the period in days required under laboratory conditions.

If two females are fertilized the same day, both will be able to lay fertile eggs on the same day. However, there may be a variation of 48 hours between one and the other when placed in cages with different degrees of moisture.

TABLE II

PREOVIPOSITION OF *A. POSTICA* (1953-54)

Num. cases observed	Period in days Minimum	 Maximum	 Average
50	2	6	3.25

Oviposition. Under field conditions ovipositing may be indistinctly made at the base of the cane or in the soils surrounding the stalk within the plant. Under laboratory conditions we used cages where we placed pieces of moistened cane bagacillo, covered by 4 or 6 layers of filter paper. The mated adults were introduced and the ovipositions observed.

The females lay their eggs on the filter paper, showing a preference for the borders of the cage's projecting parts. Once the edges have been covered with eggs, they coninue ovipositing from the outside to the centre of the cage.

When there is only one female under study in a cage, eggs are seldom found away from the borders. This is not so when there are cages with several females, in which case, after covering the edges, they seek for more space, as stated before. One female exhausts the egg laying four days after starting. The variations observed are reported in Table III.

TABLE III

EGG LAYING OF *A. POSTICA*

Females observed	Period in days Minimum	 Maximum	 Average
50	2	4	3.5

The female introduces the ovipositor with spinal-ventral movements keeping an obtuse angle with the cage's floor. Once an adequate penetration is achieved, it deposits the egg and takes the ovipositor out, gives a side step and repeats the operation until exhausting that day's laying. Eggs can be seen in orderly groups following a slightly curved line. The number of eggs laid by a single female appear in Table IV, in maximums and minimums.

TABLE IV

BIOTIC POTENTIAL OF *A. POSTICA* EGGS OBSERVED WITH 100 FEMALES

Num. females observed	Minimum	Maximum	Average
100	11	150	75

After several experiments it was found that one female will produce a larger number of eggs than when several are placed in a single cage. This is due to survival laws. Comparative data appear in Table V. The experiments were made with 20 females. Ten were put into the same cage and the average number of eggs laid was of 39.6 each. For the remaining 20 females, which were kept in individual cages, we found a maximum of 150 eggs and a minimum of 40. The average in these cases was of 108.5, which is by all means higher than the first ones.

The reproductive capacity of *Aeneolamia* is generally high, if its great laying capacity and viability are taken into consideration, while the nymphs, in different stages of development, show a great resistance to the environment under natural conditions, but not so under laboratory conditions.

TABLE V

BIOTIC POTENTIAL OF *A. POSTICA* COMPARATIVE DATA WITH 20 FEMALES

Exp. with 10 females placed in a single cage		Exp. with 10 females placed individually	
Num. eggs oviposited	Average	Num. eggs oviposited	Average
396	39.6	1,085	108.5

Egg.—Table VI shows measurements of the largest and smallest diameters in 100 eggs examined.

TABLE VI

MEASUREMENTS OF *A. POSTICA* EGGS IN A NUMBER OF 100

Largest diameter in mm.			Smallest diameter in mm.		
Min.	Max.	Average	Min.	Max.	Average
0.80	1.10	0.93	0.30	0.60	0.38

Elongated oval in shape, with dorsally pronounced anterior end and the posterior obtuse, keeled if seen from one side. Light yellow in colour, refracting at first, creamy opaque later on, as incubation advances. Faint spots appear during the process, later taking a strong orange colour in the cephalic region at both sides and at the end of the abdominal area, thus making the nymph's shape more visible. The suckling peak appears at the medium anterior ventral region until taking a well defined dark brown colour. So does the anus in the hind portion.

A well defined dark brown coloured circle is also noticeable at both sides of the medium lateral and medium spinal regions. Finally appear the compound eyes, red in colour, and by the time it is possible to discern the perfectly formed nymph (seen by transparency) ready for ecdysis.

Incubation.—Table VII gives the variation by days of the time rquired for hatching. This variation is influenced by the environmental moisture which, being satisfactory, allows the eggs to follow their normal course until hatching, but if not, they lose their turgescence and die.

TABLE VII

INCUBATION OF *A. POSTICA*

Num. cases observed	Period in days Minimum	Maximum	Average
100	13	15	13.5

Hatching.—The hatching process requires from 35 to 60 minutes, and in exceptional cases it stretches over the limit because of the nymph's little activity.

The average succession among the nymphs is from a few seconds to 10 minutes in the eggs of one laying and hatching is sometimes simultaneous for the whole laying ; in some cases the difference between emergencies is of about 24 hours.

When the nymph reaches its maximum development within the egg, the cephalic region is forced upwards in an attempt to burst the egg's membrane taking a rest of from 10 to 25 minutes, contracting and forcing until burst is achieved. It rests about 20 minutes before continuing. The compound eyes are the first to appear in complete disproportion with the rest of the body.

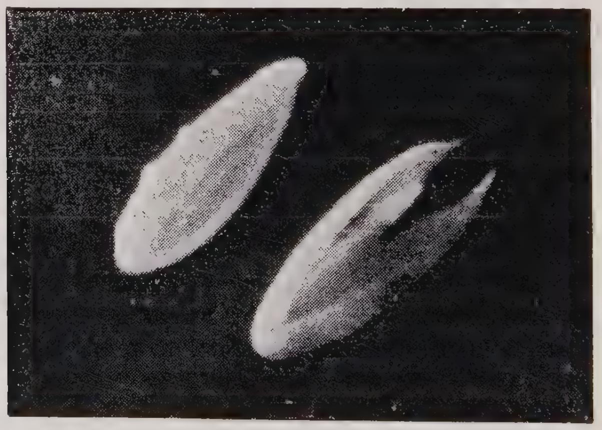


Fig. 1. View of a newly hatched egg and another about to hatch. The suckling peak is observed in this last one. Natural size : 9.29 mm. average.

After continued flexions of the body and forcing itself outwards, the nymph emerges in a sloped and forward position. It then bends itself backwards to free its legs, which are in the medium ventral line in an anterior-posterior direction ; it frees the first, second and third pair of legs successively, needing about five minutes for each of them.

However, some nymphs find it impossible to emerge and die during the different phases of the process.

Immediately after emergence, the nymph sought food.

Nymphal Instars.—It was during this phase of the biological cycle when more difficulties for breeding were found. It was necessary to change the methods and material on several occasions in order to be able to precise the number of nymphal stadium, especially in the first one and in a lesser grade in the following.

Length of the body in each nymphal stadium is specified in Table VIII, and variations between male and female are given separately.

TABLE VIII

NYMPHAL INSTARS OF *A. POSTICA*

	Length of Males (mm)		
	Minimum	Maximum	Average
1st Stadium	1.48	2.75	2.11
2nd ,,	3.00	4.25	3.62
3rd ,,	4.75	5.25	5.00
4th ,,	6.00	7.00	6.50
	Length of females (mm)		
	Minimum	Maximum	Average
1st Stadium	1.48	2.75	2.11
2nd ,,	3.00	4.50	3.75
3rd ,,	5.00	5.50	5.25
4th ,,	6.25	8.50	7.38

Table IX shows the period in days for the total duration of the nymphal stadiums.

TABLE IX

DEVELOPMENT OF THE 4 NYMPHAL INSTARS OF *A. POSTICA*

Num. cases observed	Period in days		
	Minimum	Maximum	Average
2,650	19	27	24

Moult between each nymphal stadium requires an average of 60 minutes to take place.

When the nymph is about to moult, its abdomen elongates considerably, noticing slight lateral and terminal movements followed by an almost total immobility. The new nymph forces itself up at the medium cephalic dorsal region, until burst of the exuviae is achieved, and the head of the new stadium emerges ; it rests for about 15 minutes and while it continues emerging, the opening extends to the thoracic region. The three pairs of legs are liberated in the same order as it happens with egg hatching.

When the nymph is within the foamy substance it produces, moults take place within the same substance, but if the conditions of the cane sprouts are bad, it comes out to look for good shoots in order to produce more foam. If it does not find them, it moults in the open.

The nymphal instar can be determined by the nymph's size (length, width and height), and measurements have been made only for verification purposes.

Each nymphal stadium is characterized, besides its dimensions, by the general colouring, pigmentation, wing processes and even by ways of feeding and position. Generally its colour is yellowish in its first stadium, whitish and creamy yellow in the last ; when ready to moult, they take on a very characteristic brilliant colour, which is more conspicuous. Spots appear at the abdominal region and at both sides of the body, embedded in an orange coloured zone. The spots are generally eight, and when less, it is noticed that one or two are larger, formed by small groups that in total amount to eight, perfectly defined. The difference in number of pigmented zones from the first nymphal stadiums on is due to the nymph's difference in sex.

Moisture, when high, has an important part in the development of the nymphal phases, probably even more than temperature, which comes to be a secondary factor.

The transformation of the last nymphal stadium from Imago to Adult is similar to the former moults with difference that in this stage, the wing processes give the origin to the two pairs of wings which take from 5 to 10 minutes each to stretch, first the front ones and then the hind.

The ventral part of the adult insect is orange in colour, with well defined spots in the abdominal region and at both sides of each segment ; it is also orange coloured in the dorsal region but without the dark reddish-brown spots cited. The cephalic and dorsal thoracic regions are tan with blackish stains, and the wings, of the same colour, crossed by two light stripes which divide them into three more or less equal sections; the hind wings are transparent with a characteristic venation. The genitales segments have the same dark reddish brown colour in the last abdominal segment, and it is more intense in the male.

Measurements of *Aeneolamia* adults appear in Table X.

TABLE X

MEASUREMENTS OF CEPHALIC REGION AND LENGTH OF BODY OF THE ADULTS OF *A. POSTICA* IN MM.

Males					Females				
Num. spec. measured	Ceph. region Min.	Ceph. region Max.	Length Body Min.	Length Body Max.	Num. spec. measured	Ceph. region Min.	Ceph. region Max.	Length Body Min.	Length Body Max.
100	1.80	2.10	5.50	7.00	100	2.10	2.30	7.00	7.50
Average	1.90		6.25			2.16		7.3	

LENGTH OF BODY INCLUDING WINGS AT REST

Males			Females		
Minimum	Maximum	Average	Minimum	Maximum	Average
7.00	8.00	7.45	8.50	9.00	8.80

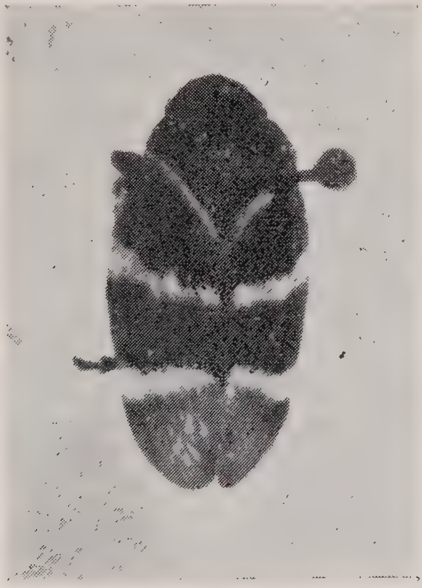


Fig. 2. *Aeneolamia* (*Tomaspis*) *postica* (Wlk.)
Adult insect Natural size with wings
Male : 7.45 mm. Female. 8.80 mm.

As per data obtained, longevity varies according to the way they are handled, but in artificial cultures the maximum was generally 6 day for the females and 3 for the males. They might possibly live longer under field conditions, because of their being in natural environments, but without exceeding much. It was also noticed that those males that do not become mated may live up to 5 days in captivity, not so the females, whose maximum noticed was of 6 days.

Habits and Activity (a) Nymphs.—Passive during the largest part of their life under artificial conditions. When hatching, under field conditions, they move within a reduced range until they find the proper feeding place. It is possible to assure that they will stay there moulting within the foamy substance they form and moving only a few centimeters until they become adults. It is not possible to achieve this artificially because the shoots used for food have a tendency to dry, making it necessary to renew them constantly.

(b) Adults.—In contrast with the nymphs, the adult is active during its whole life both under field and laboratory conditions; however, a greater activity is noticed in the males.

During its first hours of life and while its wings get stiff, the male is passive. However, once this happens it is impossible to find it in a fixed place. During the first hours of the day, they are liable to be found in the lower part of the leaves or near to the base of the cane; when the sun is warmer, they are more frequently found in the upper parts, showing a great activity. They are scared at the slightest movement.

The female is almost completely passive, and spends most of the time on the leaves of shadowy shoots, but once they reach the maturity necessary for copulation, they become more active.

A more marked phototropism is noticed in the males than in the females and this is the reason why they are more liable to be found in a larger proportion in places far away from their origin.

The complete biological cycle of *Aeneolamia* (*Tomaspis*) *postica* (Wlk.) is shown in Table XI.

TABLE XI

BIOLOGICAL CYCLE OF *A. POSTICA* OBTAINED IN THE LABORATORIES OF COSTA RICA, SIN. AND EL MANTE, TAMPS

Copulation or mating		2	days
Preoviposition		2-6	,,
Incubation		13-15	,,
Nymphal stadium		19-27	,,
	Total	36-50	,,

Population. The most or least abundance of *Aeneolamia* is influenced by three factors :

(a) Type of Culture of Sugarcane : This is probably the most important among all, as after compiling data from former years, it was verified that the effective and real damage is made in ratoon cane with three or more cuttings because of the progressive accumulation and viability of the insect. Population decreases greatly in cane with less cuttings and the presence of the insect is quite accidental on plants of first cuttings.

(b) Variation of Environment : Brues, (1923) states that resistance to environment plays an important part in the fluctuation and stability of the insects' population.

If an insect is under normal conditions of moisture, temperature, light, etc., it will develop and reproduce favourably according to its biotic potential. When an alteration in environment occurs, the insect's normal course is evidently modified and when restored, the population is recovered during the new generations, attaining its stabilization according to the cycle.

(c) Parasites and Predators : The density of population of *Aeneolamia* varies with the environment characteristics. This density is closely related to the influence of parasites and predators ; its stability depends largely on their direct action.

Parasites : A wasp from the *Trichogrammatidae* family that attacks the eggs and *Encyrtidae* which parasites the nymphs.

Predators : The bug *Castolus plagiaticollis*, a redubidae of certain importance. The Hyla frog, very effective.

However, their allied control is not higher than 5%.

A bacterial disease attacking mainly the nymphs in their last stadiums and reaching up to 40% in the cases observed, is very important.

Field Generations. Because of the strict relation between precipitation and development of *Aeneolamia*, Table XII below, which contains the generation seen, starting from the 10th of April of each year, when rains start, with a sequence that allow the rapid growth of the nymphs from eggs hibernating in a good way. This is why it is convenient to spray the insecticide for the control of the first generation of nymphs according to Table XII, or modify it according to the first precipitation followed by rains at regular intervals. Continuity and not quantity of monthly rain shall be taken as the only basis.

TABLE XII

NUMBER OF GENERATIONS OF *A. POSTICA* OCCURRING IN THE FIELDS OF EL MANTE, TAMPS. IN 1954

	Adults' emergence date	
	Maximum	Minimum
Adults of 1st generation coming from hibernating eggs	6-5-54	28-4-54
36 to 50 days after		
Adults of 2nd generation (superposed generation)	3-6-54	11-6-54
		25-6-54
36 to 50 days later		
Adults of 3rd generation (superposed generations)	23-7 -54	9-7-54
	31-7 -54	17-7-54
	14-8-54	31-7-54

If a prolonged interruption in the rain's continuity occurs, the growth of nymphs of *Aeneolamia* is totally discontinued and in this case we shall have to wait for normalization of these conditions, in order to be able to start counting the days and set the exact day for the treatments.

A rather useful practice would be the establishment of a pluviometric net to ascertain the amount of milimeters of rain and relate them to the extension of plants with several cuttings (dominant in the insects populations).

Increase in the population of *Aeneolamia* in the observation lots is due to two factors : direct product of the shoots, and product of adults migrating from nearby lots ; both natural and forced migration.

Table XIII shows the relation between adults and nymphs in attacked cane fields until before applications of insecticides.

TABLE XIII

SAMPLINGS OF NYMPHS AND ADULTS OF *A. POSTICA* PER CANE STOOL

Average plants per stool	Minimum	Nymphs per stool Maximum	Average
6	10	42	20
8 to 10	56	130	83
21	110	250	150
		Adults per stool	
6	2	2	2
8 to 10	90	150	115
21	320	346	340

CHEMICAL CONTROL

The pest appeared at La Joya, Camp. in 1950 and was immediately controlled with BHC-DDT and sulphur using the formula 3-10-40 ; one application was made with motor pump at a rate of 20 K/Ha.

Mr. A. C. Blackburn, from Trinidad, B. W. I. recommended in 1952 the use of BHC, 0.65% gamma isomer, mixed with 80 mesh limestone applied with hand sprayer over the cane's stalk, and the soil surrounding the stool at a rate of 112-224 K/Ha. (1 to 2 cwt/acre). This treatment should be used against the first generation of insects in their nymphal stage with the purpose of destroying the majority of them, and in this way it is possible to obtain a decrease of the future population of the subsequent generations.

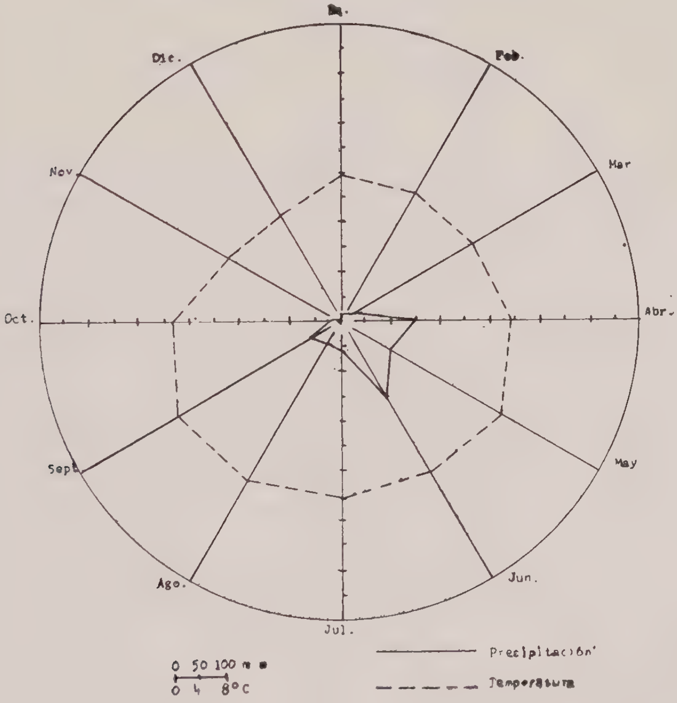
During 1953 we were controlling the nymphs of the first generation with BHC 1% gamma isomer thick inert 80-90 mesh applied at a rate of 100 to 200 K/Ha. with hand sprayers, to the stalk and the soil surrounding the stool. We also use BHC 3% gamma isomer mixed with fine inert 300 mesh and applied by plane at a rate of 25 K/Ha. for the adults.

In experiments made in 1954 we were able to prove that both for the control of the nymph and the adult, the BHC 3% gamma isomer applied by plane and mixed with 90 mesh inert at a rate of 30 K/Ha. is very effective. A control of the 90% of the population of adults insects and nymphs has been obtained by use of this formula.

A single application at the right moment, which generally coincides 2 or 3 weeks after the establishment of the rainy season, is enough to destroy the major part of the population of nymphs and adults coming from the hibernating generation. If this is not done in time, it shall be necessary to make 2 or 3 applications at a rate of 30 K/Ha. each and the conditioning of a special gadget on the sprayer's chute, which will force the insecticide to fall as near as possible to the soil in order to kill both the adults and the nymphs.

The installation of 4 to 5 pluviometric stations with maximum and minimum thermometers to control the cultivating area, is recommended ; the reports on rain and temperature help to make an estimation of the biological cycle of the different generations of *Aeneolamia* serving as a guide for the pest control procedure.

ESTACTION EXPERIMENTAL CD. MANTE



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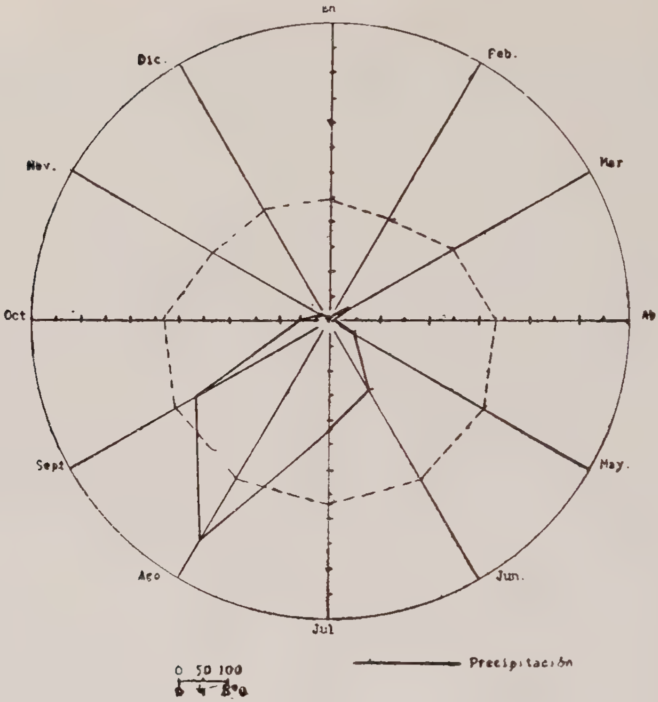
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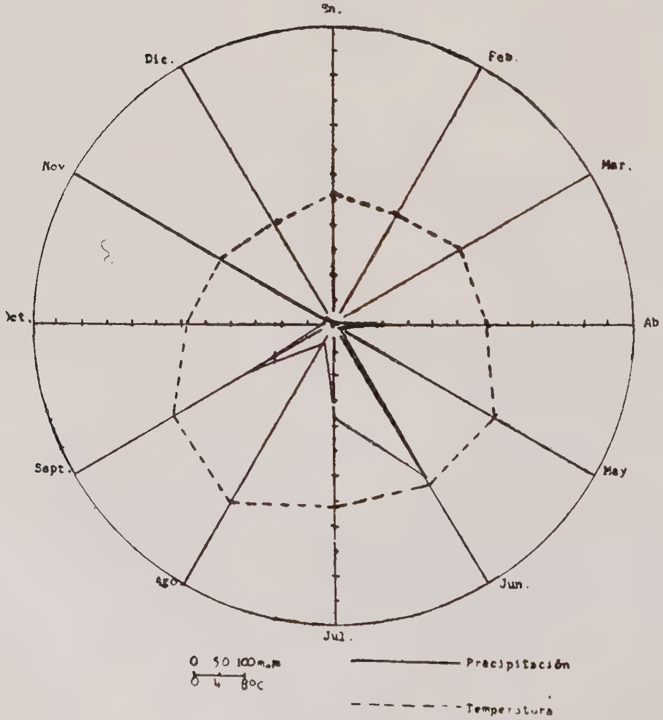
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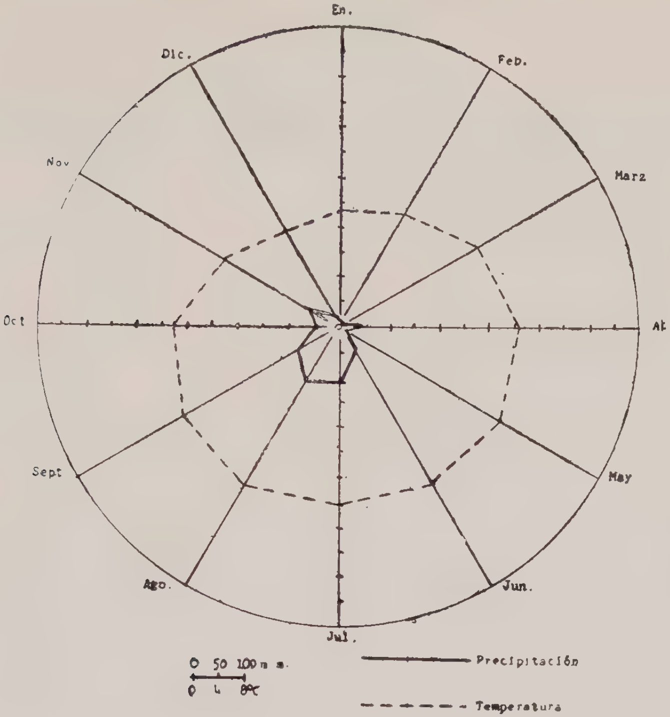
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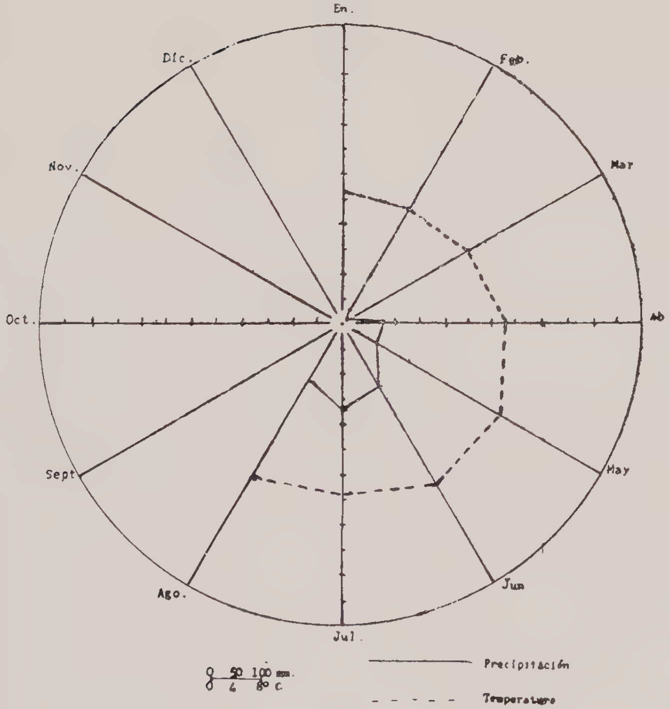
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DISCUSSION

Mr. Evans stated that the froghopper was a serious pest in Trinidad, where it had been previously controlled with BHC (used as Agrocide) mixed with lime, but after some time, the pest developed resistance to BHC and recourse had to be taken to other insecticides when Malathion was found to control the pest effectively.

In the absence of the authors the following paper was taken as read.

Paper

SUGARCANE BORER CONTROL IN LOUISIANA WITH INSECTICIDES

A.L. Dugas and E.J. Concienne
Louisiana Agricultural Experiment Station

Early attempts to control the sugarcane borer with insecticides in the United States and in other cane producing countries were not successful. The lack of an insecticide that would effectively control the borer without injuring the cane foliage and insufficient knowledge on timing of dust applications were the principal limiting factors. Indications of effective control were first obtained from the relatively high water-soluble fluorine compound, sodium fluosilicate. Hinds and Spencer (1) reported on the results of investigations with this material in 1927 and 1928, and Holloway, Haley, and Ingram (2) in 1928. With the development of cryolite, another fluorine compound which is more neutral in reaction and relatively insoluble, interest was again aroused in chemical control of the borer.

Ellisor and Eddy of the Louisiana Agricultural Experiment Station, in laboratory tests in 1936, found that cryolite was highly toxic to the sugarcane borer and in the fall of 1937 the Louisiana Experiment Station, in cooperation with the Bureau of Entomology and Plant Quarantine, of the United States Department of Agriculture, demonstrated the effectiveness of this material in the field. Development of cryolite for borer control was continued on a cooperative basis through 1941, after which time separate programmes were initiated (3).

This paper reports a summary of the work done by the Louisiana Agricultural Experiment Station since 1941 in testing cryolite and other materials against the borer and in the development of the practical application of a chemical control programme for the suppression of the pest in Louisiana. Beginning in 1943, four applications of cryolite at weekly intervals have been recommended for control of either the first or the second generation of borers. Ryania, at 40 percent concentration has been recommended along with cryolite since 1950. Dusting with cryolite or ryania is now a generally accepted practice for controlling the insect in Louisiana.

CHEMICAL CONTROL BASED ON SEASONAL HISTORY AND HABITS OF THE SUGARCANE BORER

Successful chemical control of the borer is contingent upon a thorough knowledge of the life history, seasonal history and habits of the insect. The application of insecticides must be synchronised with the hatching of the borer larvae in order to obtain maximum kill before they enter the plant.

In Louisiana, during late fall and winter, November to March, the borer is hibernating as full grown larvae in cane pieces left in the fields at harvest, in stubbles, in summer-planted cane, and some years in shoots growing from early harvested cane. Small numbers also overwinter in Johnson grass or other large stem grasses. Under normal temperature conditions, overwintered borers begin to pupate in late February and March, and moths emerge in large numbers about the first week in April. Eggs are laid on the small cane and sometimes on early planted corn for the first generation. The eggs hatch in four to eight days and the young borers work their way down into the bud or central whorl of the plant, where they feed for from one to three weeks depending upon temperatures. This feeding in the bud causes leaf signs or leaf perforations, which are the first indication of borer infestation in the spring. The larvae then move down behind the leaf sheaths and there feed for about a week or longer, the length of this period depending upon the favourableness of the weather. The time elapsing from hatching of the larva until it gains entrance into the plant is generally more than two weeks. This allows sufficient time for determining the fields that will need dusting and for making arrangement for applying the first application of the poison. First generation egg laying continues for about two or three weeks after general hatching occurs, conseqently four weekly applications of poison are normally sufficient to cover the period. In late May, deadhearts, the dying of central whorl of the plants, resulting from the feeding of first generation larvae, begin to appear. These borers reach maturity toward the end of May and the moths emerge and begin laying eggs for the second generation about the first week of June. There is usually a period of about three weeks to a month between the appearance of the last eggs of the first generation and the first eggs of the second generation. Therefore, there is no need of insecticidal applications from about the 10th of May until about the 15th or 20th of June.

A general hatching of second generation larvae occurs about the 20th of June, at which time insecticidal applications must necessarily be started. By so doing, four weekly applications of insecticides take care of the second generation in most fields. Under conditions of a heavy infestation, especially in fields of certain varieties of cane, a fifth application is sometimes necessary. The newly hatched second generation borers differ in habit from those of the first in that they very seldom do any feeding in the bud of the plant but move directly to the inside of the leaf sheaths. Although there may be some leaf feeding, especially in fields where infestations are heavy, true leaf signs are generally not common enough to be used as a criterion for selecting fields for second generation dusting. In fields where there was little or no first generation infestations, therefore no deadhearts, the only available criterion is leaf sheath feeding. In fields that had medium to heavy first generation infestations the number of deadhearts per acre is a good measure, especially in stubble fields where the first generation infestation are usually heavier than in plant cane.

It is usually about the first week of August when a general hatching of third generation eggs occurs. This generation is not so clearly defined as the first and second, but in most fields, there is a short period of time between the second and third during which no eggs are laid. There is of course more overlapping of third, fourth and the partial fifth generations.

EARLY SEASON PROGRAMME OF INSECTICIDAL CONTROL

A knowledge of the habits of the borer and the nature of cane growth revealed the apparent need of an early season poisoning programme because of the clearly defined nature of the first and the second generation and the advantages in treating the small cane.

There are usually no joints on the plant at the time of first generation attack so the protection of the plant is of no particular value. First generation control is therefore a preventive type, however, its value lies in the fact that it reduces early infestations thereby decreasing succeeding generations which actually do the damage. Benefits at harvest time depend upon a near complete destruction of the first generation over a sufficiently large area to prevent reinfestation by later generations. It is therefore necessary that a large part of the infested area be treated so as to lessen the likelihood of an influx of moths from adjoining infested fields. For instance, small experimental plots in which a hundred percent control of the first generation was obtained showed no benefits at harvest time where surrounded by infested cane.

However, at the time of second generation attack five to seven joints are formed and its control gives actual protection to joints and benefits that are measurable at harvest time. Although some benefits are lost by injury from reinfestation by later generations, the losses are not in proportion to the percentage of joints bored because the late injury is mostly in the upper joints where losses are less severe. Although outstanding harvest time differences can be demonstrated in small plot second generation tests, more effective control in the end is dependent upon a sufficiently high kill of second generation borers and a minimum of reinfestation.

The long period of time elapsing from the last application of dust until harvest therefore presents certain risks and necessitates near complete treatment of infested areas. The present trend of thought is toward extending the control period nearer to harvest which is now a possibility since some of the newly introduced varieties of cane grow rather openly at the top allowing dusts to better penetrate in later stages of growth.

EXPERIMENTAL METHODS

In the many experiments conducted during the course of these investigations essentially the same methods relative to plot sizes and arrangements, borer infestation determinations, yield records, etc., were used in all phases of the studies and are included in the general discussion of methods which follows :

Two types of tests were conducted ; small plot tests, involving hand-gun applications ; and large acreage tests of airplane or ground machine application.

Small plot tests : In the small-plot tests, a randomized arrangement of plots was employed, with each treatment being replicated at least four or five times. Each plot was 60 to 72 feet long, depending upon the length of rows. Areas of 15 to 20 feet at the ends and 2-rows between the plots were left untreated as buffers. Insecticides were applied with rotary hand-guns in the early morning before the dew dried or in the evening after the wind subsided. The rates of application averaged about eleven pounds per acre per application. Four applications were made at weekly intervals unless specified otherwise. Treatments were commenced as soon as a general hatching became evident, but before the larvae began to bore into the plants. Small plot tests were employed whenever possible in preference to large acreage tests since it is believeo that more accurate results are so obtained. Most of the small plot tests were located within the boundaries of either one or two cuts of cane, which consisted of from about 2 to 4 acres. This eliminated to a great extent the effects of differences in soil types, fertility, stand of cane, insect infestations and even rainfall which differences may interfere significantly in the evaluations of the factors under consideration. Large plots were used in order to approximate plantation conditions, so as to prevent reinfestation by later generations, in studying results from plane application and the like. However, yield records in large plots are usually unreliable.

In tests on the first generation and fall generations in summer planted cane, treatments were evaluated by the number of deadhearts and the number of borer stages surviving. The deadhearts on the centre three rows of each plot were cut and examined for borer larvae and pupae. First generation tests were discontinued after such examinations, since the benefits were erased by reinfestation of later generations. Treatment differences in number of deadheart are not measurable at harvest time. In tests involving fall generations, the summer-planted cane is usually killed by winter temperatures. Although it is not profitable to control fall generations in summer planted cane, the growth of cane and type of borer injury is similar to that at the time of first generation attack in the spring and offers an opportunity for testing the toxicity of insecticides.

In small plot tests on second and third generations the differences in borer infestations were measured by percentage of joints bored in the summer about two or three weeks after the last application and at harvest time. This furnished a record of initial control and extended control to harvest. The stalks in a 5-row foot sample on each of the centre three rows in each plot were examined for joints showing external borer holes. Infestation records were so recorded as to show the location of the bored joints in the stalk. This enabled the calculation of percentage of each joint bored, first, second, etc. from the bottom to the top joints. Only the average percentage of joints bored is given, which may sometimes be misleading since dusting tends to locate the bored joints in the upper parts of the stalk resulting in relatively less damage. Yield records were taken from the centre three rows, and a sucrose analysis obtained from a random 25 stalk sample in each plot. A record on yellow sugar cane aphid population was obtained by estimating the number of aphids in all colonies on the plants of one full length row of each plot.

In the large acreage tests, the plots consisted of six full length rows in the case of ground machine applications and one cut of two acres or more in size for plane application. Borer infestation counts were of the same nature as those in the small plot tests. In most instances no attempt was made to secure yield records, since yields over large areas are influenced to too great an extent by factors uncontrollable, such as soil variations, etc.

A summary of results of various studies presented in table form represents an average of at least four replicates in each case. An attempt was made to group several tests of a like nature in one table. In some instances only the result of one representative test is presented, although many others may have been conducted.

EARLY EXPERIMENTS WITH CRYOLITE

Investigations prior to 1942, in cooperation with the Federal Station at Houma, Louisiana, pointed out that cryolite gave a significantly better control than any other material tested against the borer. It had been found that either the first or the second generation could be controlled successfully by dusting four times at weekly intervals with undiluted cryolite.

It was obvious that additional research was needed to study the effectiveness of various dilutions of cryolite with the idea of lowering the cost of insecticide per acre, as well as improving the degree of control, especially that of the second generation. It also became apparent that there was need of definite figures on the savings in cane and sugar yields that could be expected from the control of the borer by dusting with cryolite. Since it was known that such data could not be obtained in small plots treated for first generation control and yields recorded from large plots were usually unreliable, small plot second generation test were resorted to.

EFFECTIVENESS OF VARIOUS DILUTIONS OF CRYOLITE AGAINST FIRST GENERATION BORERS

In previous work, it had been found that there were sufficient differences in the control obtained with undiluted cryolite and eighty percent cryolite to warrant the recommendation of the undiluted material. Two experiments were then planned to study the relative toxicity of undiluted cryolite and cryolite-pyrax mixtures at the same rate of application and at increasing rates of application so as to apply the same amount of sodium fluoaluminate, the active ingredient, per acre. It was thought that this would reveal the need, if any, of a higher rate of application to insure maximum control.

TABLE I.

A SUMMARY OF THE RESULTS OF TWO EXPERIMENTS WITH VARIOUS DILUTIONS OF CRYOLITE APPLIED AT THE SAME RATE PER ACRE AND AT VARYING RATES SO AS TO OBTAIN EQUAL QUANTITIES OF SODIUM FLUOALUMINATE FOR CONTROL OF FIRST GENERATION BORERS BELLEVIEW PLANTATION C.P. 29/116 STUBBLE

Treatments	Borer deadhearts		Live borer stages		Percent
	Per plot	Per acre	Per plot	Per acre	Control
	Experiment 1.				
1. Cryolite, undiluted	4.2	141	2.0	67	94
2. Cryolite-pyrax (4-1)	3.2	108	1.8	60	95
3. Cryolite-pyrax (2-1)	5.8	195	1.4	47	96
4. Cryolite-pyrax (1-1)	10.8	363	4.2	141	87
5. Cryolite-pyrax (1-2)	16.6	558	10.4	349	68
6. Check, no treatment	45.4	1525	32.8	1102	
	Experiment 2.				
1. Cryolite, undiluted 8 lbs. per acre	6.0	202	3.6	121	92
2. Cryolite-pyrax (4-1) 10 lbs. per acre	7.4	249	3.4	114	93
3. Cryolite-pyrax (2-1) 12 lbs. per acre	13.2	444	5.8	195	87
4. Cryolite-pyrax (1-1) 16 lbs. per acre	2.6	87	0.6	20	99
5. Cryolite-pyrax (1-2) 24 lbs. per acre	5.2	175	3.2	108	93
6. Check, no treatment	75.0	2520	46.2	1552	

The results of these two experiments, under conditions of a rather light borer infestation, are presented in Table I (above). In the first experiment, where all materials were applied at the rate of eight pounds per acre per application, the undiluted cryolite, cryolite-pyrax (4-1) and cryolite-pyrax (2-1) resulted in about equal control. Against heavier infestations, the undiluted materials did much better than any of the dilutions. The percent control obtained from the cyrolite-pyrax (1-1) and the cryolite-pyrax (1-2) decreased proportionally to the amount of toxicant used as would be expected.

The most significant fact revealed by the results of experiment 2 was the almost perfect control following the application of cryolite-pyrax (1-1) at double the dosage of the undiluted material. This increase in control, 99 percent compared to 92 percent, was thought to be of such significance that the cryolite-pyrax (1-1) was included in second generation tests at double the dosage of the undiluted material since it was thought that such a treatment might result in a better control through a more uniform coverage of the plants. Therefore, this treatment was included in seven such tests.

SAVINGS IN YIELD OF CANE AND OF SUGAR FROM CRYOLITE CONTROL OF SECOND GENERATION BORERS

After learning that cryolite was highly toxic to the borer, the cane growers expressed a desire for definite figures on the savings in cane and sugar yield that would result from controlling the insect by dusting with this material. In seven small plot tests on second generation the following treatments were used : cryolite at 10 pounds per acre per application ; cryolite at 12 pounds per acre per application; cryolite-pyrax (1-1) at 20 pounds per acre applied on one side of row ; cryolite-pyrax (1-1) at 20 pounds per acre applied to both sides of the rows ; an undusted check ; and sulphur at 10 pounds per acre. The sulphur treatment was used to show losses from a higher borer infestation than that expected in the check plots since it was known to cause an increase in infestation. A summary of the results of the seven tests are presented in Table II. The results are discussed according to the various factors used in measuring the differences between treatments.

Treatments : The 10 pound application of undiluted cryolite did as well as any of the treatments except in experiment 5, which was in a heavy growth of C.P. 2/116 cane. Except in this one test, there appeared to be no need of a heavier application. The cryolite-pyrax mixture (1-1) at 20 pounds per acre was not superior to the 10 or 12 pounds of undiluted cryolite. (In plane application, it is advantageous not to use more than is necessary to obtain proper coverage, since each pound costs an extra 4 or 5 cents to apply). Nevertheless, the results in experiment 5 indicated the need of a heavier application of cryolite in heavy stands of cane, especially C.P. 29/116. Sulphur applications accounted for a significant increase in borer infestation, and serves as a measure of cane losses at a higher level of borer infestation than that in the untreated checks. This effect of sulphur upon borer infestation is due to the fact that it is not toxic to the borer but it is toxic or repellent to *Trichogramma*, the egg parasite, and to the natural predators which feed on borer stages.

Since there was very little difference in the results obtained from any of the cryolite treatments only the 10 pounds of undiuted material per acre, the untreated check and the sulphur treatment will be referred to in discussing the various factors wich measure the savings from control.

Borer infestation : As measured by percentage of joints bored at harvest time, undiluted cryolite at 10 pounds per acre accounted for a reduction in borer infestation of from 50 to 60 per cent in comparison to the untreated check. Sulphur accounted for considerable increase in borer infestation over the checks.

TABLE II

SUMMARY OF THE RESULTS OF SEVEN EXPERIMENTS TO STUDY THE SAVINGS FROM INSECTICIDAL CONTROL OF SECOND GENERATION SUGARCANE BORERS BY DUSTING WITH CRYOLITE

		Borer infestation Joints bored			Yield of cane per acre		Increase over check	
	Treatments	Summer Percent	Harvest time Percent	Sucrose Percent	Actual Tons	Standard Tons	Cane per acre Actual Tons	Sugar per acre Pounds
			Experiment 1.	*Oakbluff, C.P. 29/103 plant*				
1.	Cryolite, 10 lbs. per acre	18	47	12.92	23.5	24.4	6.4	1377
2.	Cryolite, 12 lbs. per acre	10	44	12.92	24.2	25.2	7.1	1478
3.	Cryolite-pyrax (1-1)[1]	19	46	12.53	23.3	23.2	6.1	1216
4.	Cryolite-pyrax (1-1)[2]	15	43	13.01	22.5	23.6	5.4	1249
5.	Check, no treatment	54	77	11.46	17.1	17.1	135.9	2325
6.	Sulphur, 10 lbs. per acre	66	82	10.49	14.1	11.3	—3.0	—633
			Experiment 2.	*Camperdown, C.P. 29/103 plant*				
1.	Cryolite, 10 lbs. per acre	7	26	13.95	20.2	34.7	4.3	1347
2.	Cryolite, 12 lbs. per acre	8	23	14.06	30.2	35.0	4.3	1388
3.	Cryolite-pyrax (1-1)	9	29	14.43	27.2	32.4	1.3	926
4.	Cryolite-pyrax (1-1)	9	35	13.22	30.9	33.1	5.0	1037
5.	Check, no treatment	29	58	12.89	25.9	26.9	158.1	4095
6.	Sulphur, 10 lbs. per acre	51	64	12.07	25.2	25.2	—0.7	—360
			Experiment 3.	*Belleview, C.P. 29/103 plant*				
1.	Cryolite, 10 lbs. per acre	9	26	14.57	20.8	25.2	4.3	949
2.	Cryolite, 12 lbs. per acre	8	27	14.63	20.2	24.4	3.7	877
3.	Cryolite-pyrax (1-1)	8	28	14.57	20.2	24.4	3.7	845
4.	Cryolite-pyrax (1-1)	5	29	14.67	20.8	25.4	4.3	980
5.	Check, no treatment	35	49	14.17	16.5	19.3	173.7	2866
6.	Sulphur, 10 lbs. per acre	49	58	13.88	14.5	16.5	—2.0	—456
			Experiment 4.	*Belleview, Co. 290 plant*				
1.	Cryolite, 10 lbs. per acre	14	33	13.05	25.9	27.5	5.4	1525
2.	Cryolite, 12 lbs. per acre	11	27	12.64	25.9	16.2	5.4	1523
3.	Cryolite-pyrax (1-1)	19	33	12.79	24.9	25.6	4.4	1275
4.	Cryolite-pyrax (1-1)	13	32	12.72	24.9	25.4	4.4	1180
5.	Check, no treatment	33	49	11.68	20.5	20.5	147.7	3028
6.	Sulphur, 10 lbs. per acre	38	56	11.14	18.1	16.7	—2.4	—452
			Experiment 5.	*Oxford, C.P. 29/116 plant*				
1.	Cryolite, 10 lbs. per acre	18	42	12.69	32.3	32.9	1.7	973
2.	Cryolite, 12 lbs. per acre	20	42	12.93	34.3	35.7	3.7	1307
3.	Cryolite-pyrax (1-1)	19	44	12.73	33.6	34.3	3.0	1111
4.	Cryolite-pyrax (1-1)	19	48	12.69	32.6	33.3	2.0	1064
5.	Check, no treatment	31	70	11.17	30.6	28.8	126.2	3862
6.	Sulphur, 10 lbs. per acre	56	79	10.42	23.9	18.6	—6.7	1130

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1. Applied on one side of row—20 lbs. per acre.
2. Applied at the same rate but on two sides of row—20 lbs. per acre.

Experiment 6. Belleview, C.P. 29/116 2nd stubble

1. Cryolite, 10 lbs. per acre	22	29	11.58	13.1	13.1	3.4	876
2. Cryolite, 12 lbs. per acre	23	32	11.71	12.8	12.8	3.1	857
3. Cryolite-pyrax (1-1)	21	30	11.58	13.1	13.1	3.4	836
4. Cryolite-pyrax (1-1)	25	32	11.63	13.4	13.4	3.7	922
5. Check, no treatment	46	64	9.60	9.7	6.0	104.5	1014
6. Sulphur, 10 lbs. per acre	65	71	8.38	7.7	2.9	—2.0	—311

Experiment 7. Village, C.P. 28/19 stubble

1. Cryolite, 10 lbs. per acre	18	18	15.68	19.8	26.6	2.7	736
2. Cryolite, 12 lbs. per acre	13	19	15.66	19.5	26.2	2.4	722
3. Cryolite-pyrax (1-1)	18	19	15.22	18.5	24.0	1.4	403
4. Cryolite-pyrax (1-1)	15	20	15.88	19.5	26.6	2.4	783
5. Check, no treatment	41	51	14.66	17.1	21.3	176.6	3020
6. Sulphur, 10 lbs. per acre	38	47	14.95	18.1	23.1	1.0	323

A comparison of the percentage of joints bored in the summer and at harvest time reveals a significant increase even in the cryolite plots. This was due to reinfestation by third and fourth generation borers. However, the degree of increase in the cryolite treated cane is not reflected to a large extent in the yield because of the nature of late borer injury. Since the infestation records were taken so as to obtain the percentage of each joint bored, from bottom to top, it was possible to determine the location of this reinfestation on the stalk. It occurred in the upper joints above the sixth or seventh, where the effect of borer injury is considerably less as compared to injury in the lower 6 or 8 joints.

Sucrose : In the cryolite plots of the different tests, sucrose content ranged from 11.58 to 15.68 percent ; in the checks from 9.60 to 14.66 percent ; and in the sulphur plots, 8.30 to 14.95 percent. Sucrose is an important factor to the cane grower since it is the basis of converting actual tonnage to standard, upon which he is paid. The differences between the actual and standard tons of cane per acre reveals the effect of sucrose upon converted yields.

Yield of cane (*actual*) : The ultimate and most important measure of the economics of dusting cane for borer control is the increase in yield of cane and sugar which results from the treatment. The data in these experiments show that increases in yield are proportional to the level of borer infestation in the untreated checks.

In the seven tests, cryolite at 10 pounds per acre resulted in increases of 6.4, 4.3, 4.3, 5.4, 1.7, 3.4 and 2.7 tons of cane per acre over the untreated checks. Sulphur, causing a higher level of infestation reduced the yields below the checks, 3.0, 0.7, 2.0. 2.4, 6.7 and 2.0 tons per acre. In one test, sulphur accounted for one ton increase.

Yield of sugar per acre : Increases of 1377, 1347, 949, 1525, 973, 876 and 736 pounds of sugar per acre followed applications of 10 pounds of cryolite in the seven tests. Decreases below the untreated check plots due to sulphur treatment ranged from 169 to 1130 pounds of sugar per acre. In test 7, there was an increase of 323 pounds of sugar on the sulphur plots. A study of the relationship between percentage of joints bored and the yield of cane and of sugar reveals that there is a high correlation.

Synthetic and natural cryolite : The two cryolites were tested extensively to determine if there was any difference in toxicity. Considerable difficulties were encountered in the dusting qualities of both in the beginning, which was remedied by altering the particle size of the synthetic cryolite and by adding a small percentage of conditioner to the natural. After both cryolites were conditioned into good dusting materials, particularly no differences were found in control from either in hand-gun, plane and ground machine tests.

CRYOLITE VERSUS THE ORGANIC AND OTHER PROMISING INSECTICIDES

In an effort to find cheaper and perhaps more effective insecticides for control of the borer, most of the new and promising ones were tested as they became available. Benzene hexachloride, toxaphene, parathion, chlordane, ryania and sodium fluosilicate were compared with cryolite for borer and yellow sugarcane aphid control in numerous tests in 1946, 1947 and 1948.

Since the results of experiments in 1946 indicated that the organics had definite possibilities, the programme of works was expanded and accelerated the next two years to determine whether there was a place for these new chemicals and at what concentrations they would have to be used in borer control. Toxicity studies were conducted on the first generation and fall generations summer-planted cane, but many second generation tests were carried through to harvest to obtain the real evaluation of these materials in respect to ultimate gains in yield. The data of all of the experiments are too extensive to present, so only those of three representative tests are given.

The results of 35 field tests in the three years proved conclusively that benzene hexachloride, toxaphene, parathion and chlordane had no place in the sugarcane borer control programme. Although these materials showed a high toxicity to first generation and fall generation of borers, they produced significant increases of the second generation in many instances. Apparently, this condition resulted from their injurious effect upon the natural enemies of the borer. Each affected an excellent control of the yellow sugarcane aphid in all cases. Ryania, at 50 percent strength proved to be about equal to cryolite in effectiveness.

In each of three years, these organic materials compared favourably with cryolite and ryania in toxicity against the first generation and against fall generations in summer-planted cane. The results of a representative test of each are shown in Table III. The data showed that against first generation borers, benzene hexachloride produced a control of 90 percent which was considerably better than any of the other insecticides. The other organics, toxaphene and parathion did as well as cryolite or sodium fluosilicate and slightly better than ryania ; whereas, chlordane gave practically no control. The various treatments in the repesentative test against fall generations gave about the same results except that ryania was the most effective with the others about equal. The addition of sulphur or parathion to cryolite, as was the case with other organics added for yellow sugarcane aphid control, had a tendency to reduce the efficiency of cryolite. The results are representative of the fifteen tests conducted.

A summary of data in Table IV is of a representative small-plot test against the second generation followed through to harvest. These data reveal the outstanding differences experienced with the organic materials against different generations. Following treatments of cryolite, sodium fluosilicate, and ryania there were 9, 15 and 5 percent of the joints bored, respectively in the summer or about three weeks after the last dusting. Whereas, following treatments of chlordane, benzene hexachloride, parathion, toxaphene, and cryolite-toxaphene, there were 42, 32, 23, 24 and 21 percent of the joints bored, respectively,all five being greater than the 19 percent in the untreated check. There was a somewhat proportionate increase in joints bored at harvest time. It is obvious that there is a close correlation between the percentage of joints bored at harvest time for the various treatments and the corresponding sucrose content, yield of cane, sugar per ton, and sugar per acre.

TABLE III

REPRESENTATIVE TESTS COMPARING THE EFFECTIVENESS OF ORGANIC INSECTICIDES AND OTHERS WITH CRYOLITE AGAINST FIRST GENERATION BORERS AND AGAINST FALL GENERATIONS

Treatment	Deadhearts per acre Number	Live borers per acre Number	Control Percent
	First generation experiment		
Cryolite, undiluted	141	113	79
Toxaphene, 5 percent	193	101	81
Ryania, 50 percent	282	181	67
BHC, 3 percent gamma	73	52	90
Chlordane, 5 percent	697	504	7
Sodium fluosilicate, 50 percent	234	93	83
Parathion, 5 percent	202	121	78
Check, no treatment	846	544	
	Fall generation experiment		
Cryolite, undiluted	61	40	90
Toxaphene, 10 percent	234	101	74
BHC, 3 percent gamma	52	40	90
Ryania, 50 percent	40	12	97
Parathion, 5 percent	61	52	86
Sodium fluosilicate, 50 percent	52	52	86
Cryolite-sulphur	133	52	86
Cryolite-parathion	121	73	81
Check, no treatment	645	383	

TABLE IV

RESULTS OF A REPRESENTATIVE TEST COMPARING CRYOLITE AND VARIOUS ORGANIC AND OTHER INSECTICIDES AGAINST THE SECOND GENERATION OF BORERS

Treatment	Borer infestation Joints bored		Aphids per row-foot	Sucrose content	Yield of cane and sugar gain Gain over check		
	Summer	Harvest time			Cane per acre	Sugar per ton	Sugar per acre
	Percent	Percent	Number	Percent	Tons	Pounds	Pounds
Cryolite, undiluted	9	18	55.0	12.70	2.33	31	1,120
Sodium fluosilicate, 50 percent	15	21	46.0	12.68	1.29	31	939
Ryania, 50 percent	5	13	24.0	13.19	4.42	40	1,731
Chlordane, 10 percent	42	64	6.0	8.87	—6.65	—32	—1,476
BHC, 3 percent gamma	32	55	2.0	9.61	—4.88	—17	—1,007
Parathion, 5 percent	23	51	0.1	10.44	—2.87	—4	—491
Toxaphene, 10 percent	24	43	4.0	10.71	—2.72	0	—389
Cryolite toxaphene, 10 percent	21	48	9.0	10.18	—2.29	—8	—493
Check, no treatment	19	39	14.0	10.65	23.05	143	3,296
Difference for significance 5% level	12	12	11.4	1.99	3.62	30	880

Cryolite, sodium fluosilicate and ryania accounted for increases in yield of cane per acre of 2.33, 1.29, and 4.42 tons ; in sugar per ton of 31, 31 and 40 pounds ; and in sugar per acre of 1,120, 939 and 1731 pounds per acre. The five organic treatments accounted for decreases in cane yield of 2.29 to 6.65 tons per acre ; in sugar per ton of 8 to 32 pounds ; and in sugar per acre of 493 to 1476 pounds. All of the materials which caused an increase in borer infestations gave excellent control of the yellow sugarcane aphid. Cryolite and sodium fluosilicate caused heavy build up of aphids, while ryania showed a tendency to hold down the aphid population. The exceedingly high borer infestations following the use of the organics served to illustrate the tremendous losses that result from such infestations.

In other tests, where various concentrations of benzene hexachloride and toxaphene were used, the results showed that the lowest and highest concentrations were more effective than the intermediate strengths. Perhaps, the lower strenghths, although less effective against the borer were also less destructive to natural enemies and thereby resulted in better control. The highest concentrations were probably sufficiently effective against the borer to offset their destruction of natural enemies.

Increases in borer infestations also resulted from applications of 2, 4-D and from applications of parzate, the only fungicide used in a red rot borer test.

Other materials tested against the borer were heptachlor, dieldrin, aldrin, rothane, systox, pestox, DDT and EPN. Rothane is the only one of these chemicals which showed promise but did not compare favourably with cryolite or ryania.

Sodium fluosilicate. This material has shown a great deal of promise and should be tested further. The results of many tests have shown that 50 percent sodium fluosilicate is more toxic than undiluted cryolite to first generation borers and to borers in summer-planted cane. It appears to produce a high kill under conditions where the borer infestation is heavy and development has progressed beyond the optimum time for starting dust application.

Against second generation borers, sodium fluosilicate is considerably inferior to cryolite. Plant burn following the application of this material is negligible early in the year but is sometimes severe at the time when second generation dusting is done.

The various proprietary brands of sodium fluosilicate varied considerably in effectiveness, with the larger particle size dusts showing a higher toxicity.

THE YELLOW SUGARCANE APHID

With the extensive use of cryolite dusting in 1943, certain problems of no apparent significance in small-plot experimental work became increasingly important. The most significant of these was the build-up of populations of the yellow sugarcane aphid, especially following large scale second generation control, because of the toxic effect of cryolite on the natural predators of the aphid.

Under natural conditions, this aphid begins to increase in numbers during the period of second generation poisoning, about June 15 to July 20, but in the absence of poisoning a corresponding increase of natural enemies occurs and prevents a substantial build-up. It is only when the natural enemies are destroyed that the aphids appear in destructive numbers. Three to four weeks after the last application of cryolite, the predators move back into treated fields and usually within a few days completely clean up the aphid infestation and hold them in check the remainder of the season. This aphid is so scarce in April and early May, the period of first generation dusting, that very seldom is there any significant increase following early dusting.

It has been found that ryania causes very little build-up of the yellow sugarcane aphid, and that the organic poisons all effected an excellent control. In order to eliminate the aphid problem, some growers changed from cryolite to ryania for extensive second generation dusting even before sufficient data had been accumulated to show the superiority of ryania against the second generation.

Although this aphid is not known to be a vector of sugarcane mosaic it does cause some damage by killing cane leaves. Dead leaves first appear at the bottom of the stalk, since that is where the infestation starts and is usually the heaviest. The height to which the injury extends depends upon the effectiveness of the predators. Although there is very little if any loss in yields of cane resulting from most infestations, the unsightly appearance of the dead leaves causes concern among the growers.

In 1944, considerable effort was directed toward finding an effective control for the yellow sugarcane aphid with the idea of either adding an aphicide to the cryolite or applying a "knockout" application in fields where a heavy build-up occurs after completing the regular cryolite dustings. Four forms of nicotine, Black Leaf 40, Black Leaf 10, Black Leaf 155, and Black Leaf Dry Concentrate were tested at strengths of one, two and three percent.

Where the various nicotine dusts were applied by hand-gun in fields receiving the four weekly cryolite applications, four applications of the 3 percent Black Leaf 40 dust was the only one which resulted in a relatively high reduction of aphid population. Although where control was obtained there was little apparent difference in the degree of leaf injury resulting from aphid feeding. This treatment would be almost prohibitive from a cost standpoint.

The most satisfactory aphid control was obtained in a plane test in which varying numbers of applications of nicotine were applied with the cryolite, and a treatment where a 3 percent Black Leaf 40 dust was applied previous to the four cryolite application. The results in Table V reveal that all of the treatments prevented a build-up, but the 3 percent Black Leaf 40 treatment previous to the cryolite applications was the only one which reduced the population considerably below the undusted checks. There was a 78 percent increase in aphid population in the plots receiving only cryolite.

TABLE V

SUGARCANE APHID POPULATION FOLLOWING VARYING APPLICATIONS OF NICOTINE WITH CRYOLITE AND CRYOLITE ALONE WHEN USED AGAINST SECOND GENERATION BORERS, FRANKLIN, 1944

Treatments	Aphids per row foot				Per cent control
	1st count	2nd count	3rd count	Average	
1. Nicotine, 1% (Black Leaf 4 applications)	145	211	292	216	46
2. Nicotine, 2% (Black Leaf 10) 1st and 4th applications	152	318	164	211	47
3. Nicotine, 1% (Black Leaf 155) 4 applications	78	161	262	167	58
4. Nicotine, 2% (Black Leaf 155) 1st and 4th applications	107	262	212	194	52
5. Nicotine, 3% (Black Leaf 40) prior to 4 cryolite applications	95	137	155	129	68
6. Cryolite, alone	357	792	54	401	—78
7. Check, no treatment	188	472	16	225	—

In later tests some of the organic insecticides were added to cryolite in an effort to control the aphid. In most instances these showed a tendency to prevent the build-up of a high population, but in turn lowered the effectiveness of cryolite against the borer.

In 1951, highly significant control was obtained from the use of the new systemic poisons. As the data in Table VI shows, Systox, Pestox and Metacide effected excellent controls. One application of these materials remained effective for at least a month after which time several species of predators became sufficiently numerous to destroy the infestation throughout the field including the untreated plots. Yield records showed no significant increase in yield of cane or sugar from the control of this heavy population of aphids which were increased to a high level with cryolite dustings before the one application of systemics were made. It appears that these materials are extremely effective against the heaviest kind of an infestation.

TABLE VI

COMPARATIVE EFFECTIVENESS OF VARIOUS INSECTICIDES FOR CONTROL OF THE YELLOW SUGARCANE APHID, 1951

Treatment[1]	Aphid population per 40 row feet							
	6/7/51 Pre-application		6/8/51 1 day after		6/15/51/ 1 week after		7/10/51 1 month after	
	Colonies	Aphids	Colonies	Aphids	Colonies	Aphids	Colonies	Aphids
1. Parathion, 1% dust	156	7,154	157	8,485	223	15,523	2	13
2. Lindane, 1% dust	138	6,769	163	8,219	240	15,687	4	13
3. Systox spray, 2 pints/100 gal.	170	11,786	5	9	0.3	1	3	24
4. Pestox spray, 3 qts./100 gal.	139	6,065	19	102	3	13	3	23
5. TEPP spray, 1/3qt./100 gal.	213	18,353	19	1,054	136	4,960	1	3
6. Metacide spray, 3/4 qt./100 gal.	204	13,507	3	10	27	158	3	15
7. Toxaphene spray, 3 lbs. technical/A	132	3,517	124	3,129	139	4,714	5	47
8. Check, no treatment	211	16,949	211	14,449	378	30,726	9	61

CRYOLITE VERSUS RYANIA

In the search for more effective insecticides for controlling the borer, the only one which showed great promise from the start and proved to be even superior to cryolite on generations after the first was ryania. The first work with ryania was in 1945 and studies comparing it with cryolite have continued to the present time.

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[1] All sprays were applied at the rate of 100 gallons per acre.

Concentrations of ryania ranging from 20 to 75 percent were tested to determine the most effective and economical strength. It was found that under most conditions the 40 percent was as good as the higher concentrations but against heavy infestations the 50 percent was slightly more effective at the same rates of application. A slightly heavier dosage of 40 percent dust has given the same control as the usual dosage of 50 percent.

Undiluted cryolite was compared with either or both 40 and 50 percent ryania in 13 tests against the first generation and fall generations. The average survival of borers in the cryolite treated plots was 119 compared to 120 in the ryania plots. Cryolite accounted for an average control of 91 percent while ryania gave 89 percent control.

In 17 second generation tests, Table VII, cryolite showed an average infestation of 16 and 22 percent in the summer and at harvest time, and ryania 11 and 18 percent. Cryolite accounted for an average gain of 3.17 tons of cane per acre ; 15 pounds of sugar per ton ; and 841 pounds of sugar per acre. In comparison, ryania gave an average gain of 4.13 tons of cane per acre ; 18 pounds of sugar per ton ; and 1,088 pounds of sugar per acre. The yellow sugarcane aphid population averaged 47 per row foot following cryolite applications and 15 following ryania.

The superior gains from ryania in controlling the third generation and the second and third are also shown in Table VII.

Various activators such as n-propyl isome, piperonyl cyclonene, and others have been used with lower concentrations of ryania in comparison with 40 percent without the activators. In three experiments, some of the materials have shown promise, but to date the data is still inconclusive.

TABLE VII

A SUMMARY OF THE COMPARATIVE EFFECTIVENESS OF CRYOLITE AND RYANIA IN NUMEROUS EXPERIMENTS IN WHICH THE TWO MATERIALS WERE INCLUDED IN THE TREATMENTS

Treatment	Number of tests	Borer infestation Joints bored		Increase over check Yield of cane and sugar			Aphids per row-foot.
		Summer	Harvest time	Cane per acre	Sugar per ton	Sugar per acre	
		Second Generation Control					
Cryolite	17	16	22	3.17	15	841	47
Ryania	17	11	18	4.13	18	1,088	15
		Third Generation Control					
Cryolite	3	33	36	2.42	11	635	—
Ryania	3	27	29	3.12	14	788	—
		Second and Third Generation Control					
Cryolite	2	23	23	4.54	10	1,062	—
Ryania	2	12	14	6.04	14	1,445	—

AN EFFORT TO EXTEND THE CONTROL PERIOD BY POISONING FOR THIRD GENERATION

A more recent trend in this research programme has been toward extending the control period to include the third generation, thus shortening the period of time from the last application to harvest time and thereby lessening the dangers of reinfestation ; also, to prevent heavy damage in certain fields which show a light second generation infestation but later become heavily infested by an influx of second generation moths. The latter is especially so under condition of stunted growth due to lack of moisture and the like. These tests also furnished more information on the comparative effectiveness of ryania and cryolite on second and third generations.

In some early tests to determine the efficacy of third generation control, the results were generally unfavourable. The cane was already badly injured from heavy second generation attack, consequently no significant gains could be measured from preventing injury by the third generation. The first real evidence of the possibilities of savings from third generation control was in 1947, as revealed by the results of a small-plot test in cane in which conditions were ideal for such. In this field, as was the case in many other fields this particular year, there was a rather light second generation infestation followed by a heavy third. The cane was stunted from lack of moisture and was therefore more susceptible to late injury. In fact there were so few joints on the cane at the time that the degree and location of injury on the stalk approximated that which normally exist at the time of the second generation.

The increase in yield of cane and sugar from the different insecticides were comparable to those received in other tests from second generation dusting as shown in Table VIII. Ryania was considerably more effective than cryolite or any of the other materials. It resulted in a 5.26 ton increase in cane and 1215 pounds of sugar per acre compared to 3.40 and 997 for cryolite. The savings from toxaphene was rather surprising, especially considering the bored joint infestation.

The significant gains resulting from ryania indicated the need of third generation control where conditions of borer infestation and cane growth would justify it.

In 1950, a test was conducted in C. P. 36/105 plant cane to determine the possibility of extending the dusting period in cane in which there was evidence of a high second generation infestation. The aim was to measure savings from second generation control, third generation, and a combination of the two. Ryania and cryolite were compared in these three control schedules. A treament of a heavy application of 40 percent ryania on both generations was also included in order to obtain the best possible control against which might be measured the degree of reinfestation occurring in the second generation treated plots. The results are given in Table IX.

The data show that the greatest gains resulted from second generation control but significant gains were also obtained from control of the third generation in the plots which received no second generation poison. In the case of ryania, it would have been profitable to extend the dusting period to include the third for maximum results. It is evident that the eight heavy applications of 50 percent ryania gave the best protection but that treatment would not have been as profitable as the regular 12 pound applications.

Other small plot tests as well as several plane tests in 1952 showed the need of extending the control into the third generation under certain conditions.

TABLE VIII

EFFECTIVENESS OF VARIOUS INSECTICIDES FOR CONTROL OF THIRD GENERATION BORERS. MARTIN RIDGE PLANTATION, 1948

Treatment	Borer infestation			Increase over check		
	Summer Percent	Joints bored Harvest time Percent	Sucrose Percent	Cane per acre Tons	Sugar per ton Pounds	Sugar per acre Pounds
1. Cryolite, undiluted	21	30	11.64	3.40	23	997
2. Ryania, 40 percent	11	18	11.51	5.26	20	1,215
3. Sodium fluosilicate, 50 percent	25	34	11.57	1.15	22	621
4. Toxaphene, 15 percent	29	34	10.57	3.46	5	584
5. Chlordane, 5 percent	35	44	9.89	0.85	—6	—11
6. Check, no treatment	32	39	10.27	20.02	135	2,703
7. Difference required for significance 5% level	11	9	0.92	3.58	16	647

PRACTICAL APPLICATION OF INSECTICIDAL CONTROL PROGRAMME

The insecticidal control of the sugarcane borer with cryolite and ryania is now an established field practice for combating this pest in Louisiana. Either the first or second generation is controlled by dusting with undiluted cryolite or 40 percent ryania. By starting dust applications when a general hatch of young borers appear but before they begin to enter the plant, four weekly applications of insecticides for either generation are usually sufficient. Howevr, recent studies have shown the need for a fifth application in some fields and the possibility of less than four in others. It has also become apparent that there is need of extending the dusting period nearer to harvest to include the third generation where infestations are sufficient to warrant the expense.

TABLE IX

COMPARATIVE EFFECTIVENESS OF CRYOLITE AND RYANIA FOR CONTROL OF THE SECOND, THIRD AND THE TWO GENERATIONS TOGETHER. POPLAR GROVE PLANTATION, C.P. 36/105, 1950

	Borer infestation		Analysis		Increase over check		
Treatment	Joints Bored Summer Percent	Joints Bored Harvest time Percent	Sucrose Percent	Purity Percent	Cane per acre Tons	Sugar per ton Pounds	Sugar per acre Pounds
			Generation, 2nd only				
Cryolite	19	31	14.14	80.89	4.82	16	1,371
Ryania	14	22	14.37	80.73	6.21	14	1,586
			Generation, 3rd only				
Cryolite	35	40	13.94	80.58	2.48	7	652
Ryania	32	34	13.94	80.68	2.37	8	659
			Generation, 2nd and 3rd				
Cryolite	20	21	14.79	82.25	5.26	21	1,612
Ryania	13	17	15.05	82.95	7.47	26	2,230
			Generation, 2nd and 3rd				
Ryania, heavy	8	10	15.15	82.57	8.39	28	2,491
Check, no treatment	41	58	13.48	79.99	25.43	184	4,679
Difference required for significance 5% level	9	6	0.44	2.12	2.07	7	423

The need of systematic checking of fields to properly select areas needing dusting according to the minimum borer infestation requirements seems to become increasingly more important. The criteria for selecting fields include the number of borer eggs masses per man hour ; the number of stools of cane showing leaf signs or perforations ; the number of deadhearts ; and the number of stools showing leaf-sheath feeding.

The programme involves the control of borers on a plantation or community basis so that it begins by treating all cane acreage known to be sufficiently infested for first generation. This prevents an increase of borer population in the more heavily infested fields and a spread into adjacent cane, thereby reducing the amount of acreage that requires dusting later in the season. Infestations developing later are controlled by second generation dusting. It is being recommended for 1953 that third generation control be resorted to where conditions of cane growth and borer infestation justify the expenditure. However, dusting of a small part of a large infested area on a plantation or of a small farm surrounded by infested cane for the first generation is not recommended, because of the possibilities of reinfestation by later generations from nearby untreated cane.

The first year the programme was initiated in 1943. Only ground machines were employed in applying the cryolite. One year was sufficient to convince the growers that ground machines were not practical for extensive use in sugarcane fields. Airplanes are now used exclusively for sugarcane dusting. An airplane can average about 300 acres of dusting per morning between 5.00 O'clock and the time the wind makes conditions unfavourable. The present cost of plane application in sugarcane is four cents per pound.

On some plantations which formerly suffered severe losses from borer damage year after year, one year of general dusting reduced the infestation to a low level and only nominal dusting thereafter has been necessary to hold the infestation below damaging numbers. On a majority of places this has not been true, and it has been necessary to dust about the same amount each year depending upon the extent and degree of infestation. The severe losses once experienced are not common now, since a large part of the areas normally heavily infested are treated each year. The amount of acreage treated each season has varied with the infestation. On a particular farm, some years no dusting is necessary, but the average amount over a period of years would approximate about one third of the cane acreage.

There is much interest in the possibilities of applying this insecticidal control programme of the borer in many of the tropical cane growing countries. It appears that areas where the winters are not severe enough to kill down the cane so that all of it starts out at approximately the same stage of growth in the spring, and where there is no definite hibernation period of the borer, there would perhaps be no place for an overall control programme. This would eliminate control in the small cane before joints begin to form, which would be similar to the first generation programme in Louisiana. It would then be a matter of starting dust applications as joints begin to form and continue the applications until a sufficient number of joints have been protected or until the natural enemies have increased to the point where they would continue the control. This would then involve determining the necessary interval between application and the number that would be needed. Infestation counts taken by location on the stalk at the termination of the dusting and again at harvest time would portray the degree of initial control and harvest time control as well as the pattern of injury as to location of bored joints. Other significant problems would include the effect of insecticides on populations of aphids and natural enemies of the borer and other insect pests. If it is assumed that the organic insecticides would be even more objectional than in Louisiana because of their toxicity to the many more predators and parasites present in most tropical countries, then the more likely insecticides to work with would be cryolite and ryania. Since the yellow sugarcane aphid is a serious economic pest in many cases, perhaps cryolite could not be used without an aphicide or even ryania.

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DISCUSSION

Mr. Wagle stated that a dosage of 10 lbs. of cryolite used successfully by the authors did not work well in Bombay State, where even as much as 20-40 lbs. of cryolite dust were used without success for controlling the top borer (*Scirphophaganivella*) in October-planted crop. He attributed the cause of the failure to the fact that the borer larvae remaind exposed on the plant surface for a much shorter period before entering the plant than they did in Louisiana (about two weeks) and thus afforded enough time for chemical treatment.

Mr. A.N. Kalra observed that he had tried ryania dust against the top borer in the Punjab and the results obtained were as good as those obtained with BHC. He felt that four weekly dust ings suggested by the author, perhaps for each brood of the pest, would mean 16-20 dustings for 4 or 5 broods of the pest throughout the season. This would prove highly uneconomical and, therefore, there was need for trying an insecticide with good residual effect.

In the absence of the authors the following paper was taken as read.

Paper

THE EFFECT OF TEMPERATURE AND HUMIDITY ON THE DEVELOPMENT OF THE SUGARCANE STEM BORER *CHILOTRAEA INFUSCATELLUS* SNELL

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INTRODUCTION

In India considerable amount of work on pests of sugarcane has been in progress during recent years. Special schemes have been financed for controlling the stem and root borers by means of the egg-parasite, *Trichogramma evanescens minutum* Riley, but the results about the efficacy of this parasite have not been conclusive. At some places the liberation of the parasites has proved significantly effective in reducing the pest population e.g. at Motihari (Bihar), whereas at other places, e.g. Nellikuppum (Madras), the utility of the parasite could not be established (1). This inconsistency of results clearly indicates the necessity of a critical investigation both of the pest as well as the parasite.

Of a number of stem borers, *Chilotraea infuscatellus* is known for its depredations throughout India. What *Diatraea saccharalis* is to other sugarcane growing countries such as Louisiana, British Guiana, Cuba etc., *C. infuscatellus* is to India (4). Hence this species was selected for ecological investigations under controlled conditions.

MATERIAL AND METHOD

The insect material used was collected from the farm of I. A. R. I. at New Delhi and also from the farms of I. A. R. I. sub-stations at Karnal (Punjab) and Pusa (Bihar). The main culture was maintained in the room. The batches of freshly laid eggs were kept in small specimen tubes at various combinations of temperature and humidity for study of subsequent developmental stages. The freshly hatched larvae were transferred to the leaf spindle of the cane and when they became slightly bigger they were fed on cane sets. These sets containing larvae were kept in jars at different constant temperatures. The sets were changed daily at higher temperatures of 30°, 35° and 40°C and on alternate days at lower temperatures. The larvae that pupated were removed daily and kept in tubes with both ends open and the tubes kept in desiccators at different temperatures. The moths meant for the study of their longevity were kept similarly and given 5% solution of glucose as food.

The six constant temperatures at which studies were carried out were 12, 20, 25, 30, 35 and 40°C. The temperatures were maintained in enclosures with thermostatic controls.

The different relative humidities used in the experiments were 30, 60 and 90%. They were maintained in desiccators by various concentrations of KOH solution in water.

DEVELOPMENT

(*i*) *Diapause*

Several investigators have studied (2, 3, 4) the life and seasonal history of the pest in Northern India and reported that the pest hibernates in larval stage during winter. As they did not carry out rearing at artificially maintained high temperatures during the supposed period of hibernation, their observations could not throw definite light on the question whether the larvae undergo a true physiological hibernation or their activity and rate of development simply slow down to the minimum merely in response to low temperature. During the present investigations nearly 200 larvae were received from Pusa (Bihar) in the months of November and December. These larvae were kept at constant temperatures of 25°, 30° and 35°C and a few were kept in the Stevenson's screen in the field. The idea in keeping some larvae in the Stevenson's screen was to keep these larvae under as natural conditions of temperature and humidity as possible and Stevenson's screen is supposed to be the best enclosure possible for this purpose. Majority of larvae exposed to high constant temperatures could not be induced to regain normal activity and to pupate. Out of 150 larvae at controlled temperatures only 15 pupated. Out of those kept in Stevenson's screen some remained alive upto March and out of 30 larvae 6 pupated and emerged during this period. This suggests that there is some physiological adaptation which inhibits further development of the majority of the larvae even when kept at favourable temperatures.

(*ii*) *Egg Stage*

(*a*) *Effect of temperature on development.*

Incubation period :—The incubation period has been reported to be varying btween 3-4 days at Anakapalle (Andhra), 4-6 days at Pusa (Bihar) and 4-7 days at Shahjahanpur(U.P.). The results of our observation, given in Table I, show how incubation period varies with temperature. The minimum and maximum variation and the average incubation period at different humidities at each temperature and the index of development are shown in Fig. 1.

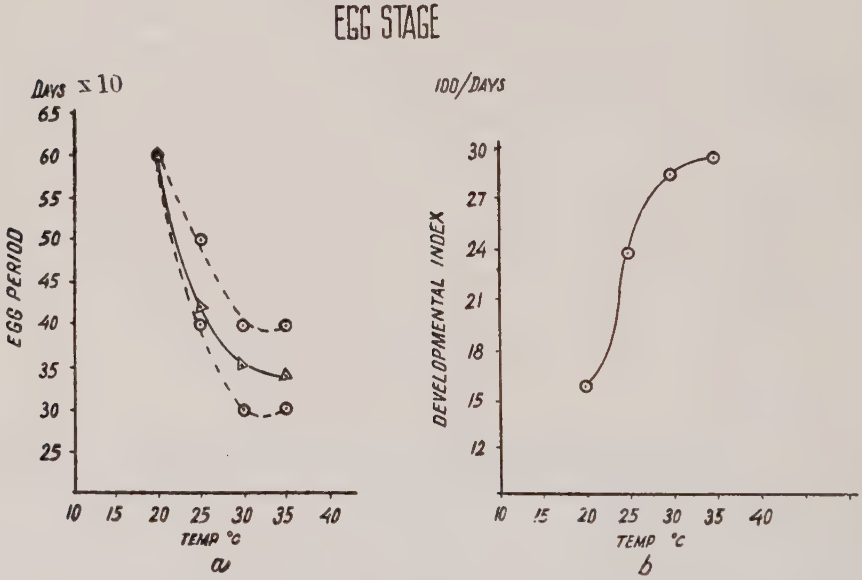

Fig. 1. (a) Egg periods P(multiplied by 10) and (b) developmental index 100/P at different temperatures. The continuous line with triangles represents the average taking all the humidities into consideration and the broken lines represent the extremes of variation observed. The circles represent the different values observed once or more than once.

TABLE I

INCUBATION PERIOD AND VIABILITY PERCENTAGE UNDER DIFFERENT COMBINATIONS OF TEMPERATURE AND HUMIDITY

	R.H. 30%			R.H. 60%			R.H. 90%		
Temp. °C	No. of eggs kept for hatching.	Incubation period (Days)	Viability %	No. of eggs kept for hatching	Incubation period (Days)	Viability %	No. fo eggs kept for hatching	Incubation period (Days)	Viability %
12	50	No hatching	Zero	70	No hatching	Zero	67	No hatching	Zero
20	60	6 ± 0	46.6	39	6 ± 0	61.5	44	6 ± 0	77.3
25	40	4 ± 0	77.5	52	4 ± 0	63.7	109	4.6 ± 0.06	69.7
30	73	3.6 ± 0.06	49.3	61	3.4 ± 0.07	85.2	142	3.8 ± 0.04	85.9
35	43	3 ± 0	53.5	92	3.5 ± 0.04	42.4	163	3.8 ± 0.03	75.4
40	101	No hatching	Zero	91	No hatching	Zero	121	No hatching	Zero

Lower Limit :—The lower limit for the development of the eggs of *C. infuscatellus* seems to be near 12°C. At 12°C and 90% relative humidity eggs were kept for nearly 40 days, but they failed to hatch. Some development did take place, as the eggs turned black indicating the formation of embryos in them but no further development could be observed till they died and shrank. Similarly at other relative humidities of 30% and 60% also the eggs did not hatch. Hence this temperature is too low to allow the completion of development.

Upper Limit :—At 40°C and all the relative humidities tried the eggs did not hatch (Table I). Only at 90% relative humidity the eggs showed some development for two days and turned brownish, but after that they died ; at other humidities they got dried up even after 24 hours. Hence 40°C is too high for the successful hatching of the eggs.

(*b*) *Effect of humidity on development of eggs.*

The effect of humidity on the development of the eggs is very slight if at all. As the differences, where they exist, are less than a day and the observations have been taken at 24 hours interval, much significance is not attached to the differences.

(*c*) *Effect of temperature and humidity on viability of eggs.*

The effect of temperature and humidity on viability of the eggs is given in Table I. The highest percentage viability at 20°, 25°, 30° and 35°C was observed at the relative humidities of 90%, 30%, 90% and 90% respectively. On the other hand under the relative humidities of 30%, 60% and 90% the maximum percentage hatching was at 25°C, 30°C and 30°C respectively.

(*iii*) *Larval Stage*

(*a*) *Effect of temperature on development.*

Larval period :—In nature the larval period varies considerably at different places and at different times of the year. At Pusa (Bihar) it is reported to be varying between 3 and 4 weeks and at Shahjahanpur (U. P.) between 16-24 days in summer and 141-171 days during winter.

Similarly it has been observed during our studies that temperature affects the rate of development of larvae immensely as is summarized in Table II. The average larval period at 20°, 25°, 30° and 35°C is 41.9, 31.2, 28.2 and 27.2 days respectively. The variations in the larval period at the respective temperatures along with the average larval period and index of development have been plotted in Fig. 2.

Lower Limit :—The lower limit for the development of larvae lies near 12°C. The freshly hatched larvae kept at this temperature could not develop and even the increase in size was negligible ; generally they died after 15 to 20 days.

Upper Limit :—Just as 12°C is too low, 40°C is too high to allow the completion of development of larvae. Out of a total of 52 larvae kept at this temperature not even one pupated. They fed and moulted but could not complete development and ultimately died.

TABLE II

LARVAL PERIOD AND VIABILITY PERCENTAGE AT DIFFERENT TEMPERATURES

Temperature °C	No. of larvae reared	Average larval period (days)	Viability %
12	37	No pupation	zero
20	53	41.9±1.3	18.8
25	112	31.2±1.6	23.2
30	124	28.2±1.24	20.1
35	115	27.2±1.38	16.6
40	52	No pupation	Zero

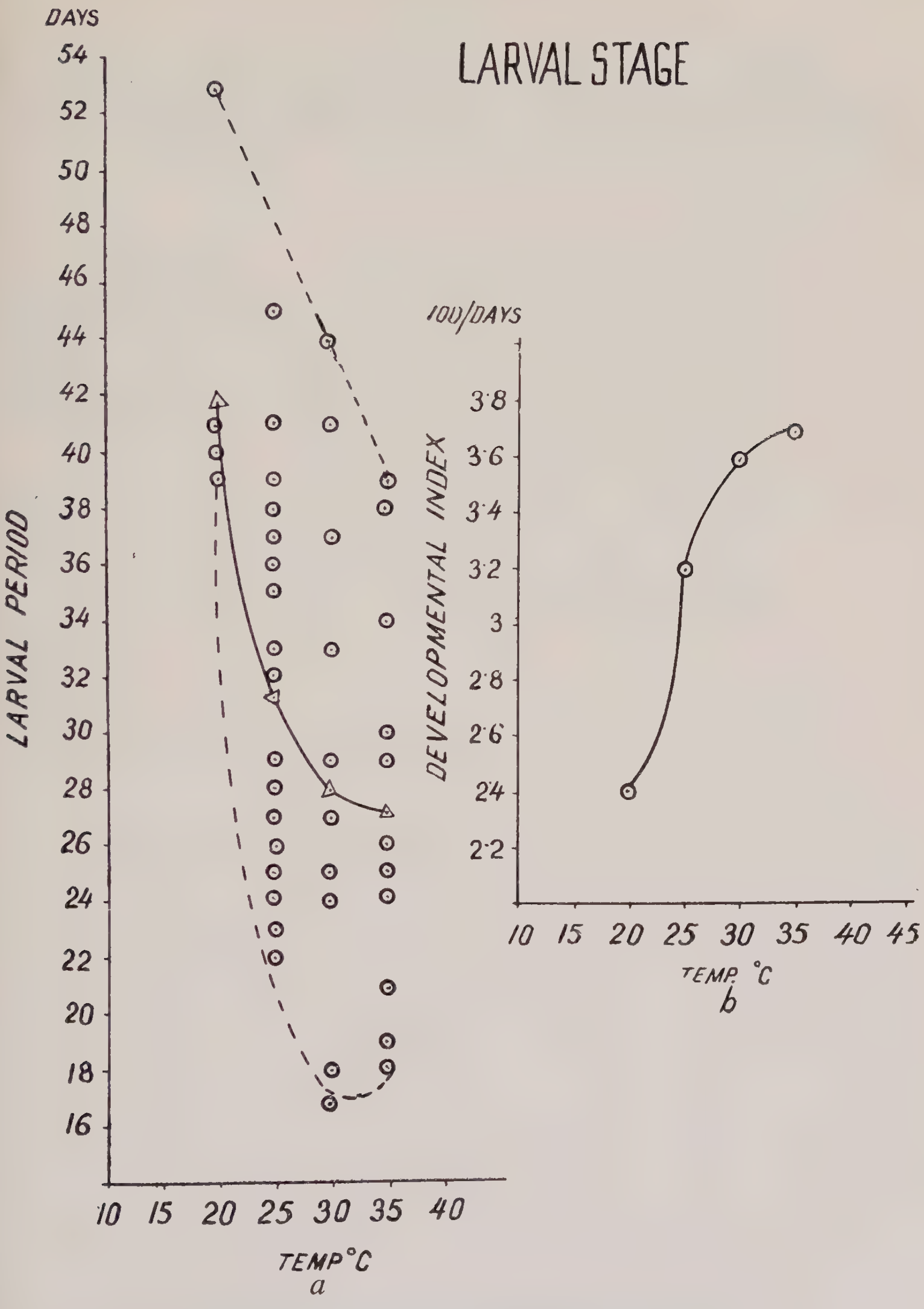

Fig. 2. (*a*) Larval periods P and (*b*) developmental index 100/P at differen. temperatures ; further explanation as in Fig. 1.

(*b*) *Effect of temperature on viability of larvae.*

The effect of temperature on the percentage viability of the larvae of *C. infuscatellus* is given in Table II. At 25°C the highest number of larvae pupated successfully, while at temperatures higher or lower than 25°C the percentage viability decreased with rise or fall of temperature.

(*iv*) *Pupal Stage*

(*a*) *Effect of temperature on the development.*

Pupal period :—The duration of pupal stage was found to be varying from 6 to 12 days at Pusa (Bihar), 6 to 10 days at Anakapalle (Andhra) and 4 to 10 days at Shahjahanpur (U. P.), at different times of the year. Results of our observations at various combinations of temperature and humidity are summarized in Table III. The average pupal period and the variations and the index of development of pupae are given in Fig. 3.

The Lower Limit :—The lower limit for the development of the pupae seems to lie near 12°C at which the development was extremely slow. At 12°C and 90% relative humidity the pupal period was exceptionally long i.e. 60 days.

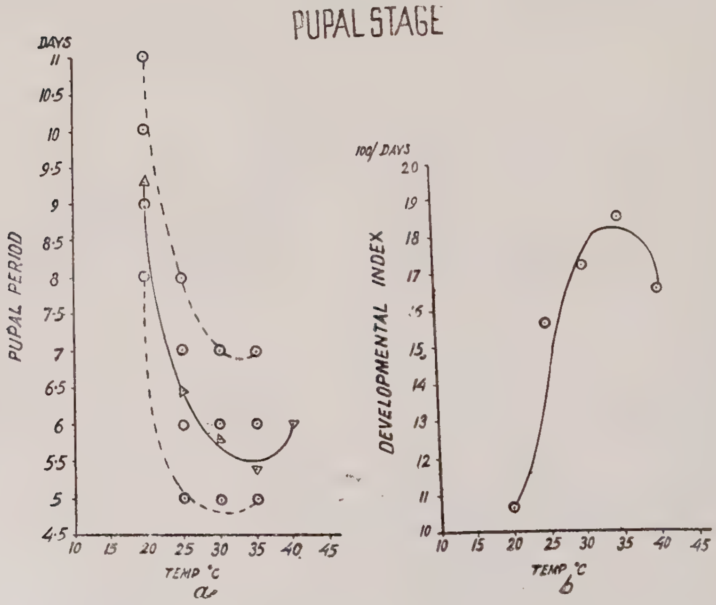

Fig. 3. (*a*) Pupal periods P and (*b*) developmental index 100/P at different temperatures ; further explanation as in Fig. 1.

TABLE III

PUPAL PERIOD AND PERCENTAGE VIABILITY UNDER DIFFERENT COMBINATIONS OF TEMPERATURE AND HUMIDITY

Temp. °C	30% R.H.			60% R.H.			90% R.H.		
	No. of pupae reared	Pupal period (Days)	Viability %	No. of pupae reared	Pupal period (Days)	Viability %	No. of pupae reared	Pupal period (Days)	Viability %
12	6	No emergence	Zero	6	No emergence	Zero	12	60	16.6
20	12	10.3 ± 0.21	83.3	15	9.3 ± 0.15	66.6	12	8.5 ± 0.17	83.3
25	15	6.8 ± 0.20	66.6	19	6.3 ± 0.13	68.2	16	6.3 ± 0.16	87.5
30	16	6.2 ± 0.22	75	13	5.6 ± 0.16	76.9	17	5.7 ± 0.16	88.2
35	18	5.3 ± 0.17	50	14	5.5 ± 0.22	71.4	15	5.6 ± 0.14	93.3
40	12	No emergence	Zero	12	6	16.6	10	6	20

Upper Limit :—Unlike the other two developmental stages eggs and larvae which could not complete development at 40°C, a few pupae did emerge at 40°C with relative humidities of 60% and 90%, but the duration of development was longer than at 35°C indicating that 40°C is definitely beyond the temperature of maximum development. Further the injurious effect of this temperature on the insect was manifested in another way as all the moths that emerged were totally deformed. Thus although the upper limit of development for the pupae might be even above 40°C the development even at 40°C is practically ineffective as the moths that emerge are disabled. Hence from the economic point of view the upper limit can be safely kept as 40°C.

(*b*) *Effect of humidity on development of pupae.*

The effect of humidity on the development of pupae is given in Table III. Low relative humidity of 30% causes a slight delay in the emergence of moths at 20°, 25°, and 30°C. This effect though slight is just the reverse of the egg stage. At 40°C the R.H. of 30% is too low to allow successful emergence. At 60% and 90% relative humidity the pupal periods do not differ appreciably except at 20°C, where the development is faster at 90% R. H. and at 12°C where some development does take place at 90% R.H.

(*c*) *Effect of temperature and humidity on the viability of pupae.*

At both the extremes of temperature i.e. 12°C and 40°C the percentage viability of the pupae is markedly reduced (Table III). At 20°,25°,30° and 35°C the highest percentage viability is at 30% and 90%, 90%, 90% and 90% respectively. Thus 90% relative humidity appears to be comparatively more favourable. At relative humidities of 30%, 60% and 90% the highest percentage viability has been at 20°C, 30°C and 35°C respectively.

(*v*) *Longevity of the adult*

The observations on the longevity of the moths both male and female under different combinations of temperature and humidity are given in Table IV.

TABLE IV

LONGEVITY OF ADULT MOTHS IN DAYS UNDER DIFFERENT COMBINATIONS OF TEMPERATURE AND HUMIDITY

Temperature °C	30% R.H.		60% R.H.		90% R.H.	
	Male	Female	Male	Female	Male	Female
12	Not studied		12	9	16	14.5
20	6.6	6.2	6.3	6.3	5.7	7
25	6	5.7	6	5	5	4.5
30	3	3	3.3	3.5	4.2	4
35	3.2	3	3.3	3	4.3	3
40	2	2	2.5	2	2.5	2

At the lowest temperature of 12°C both male and female live longest and with the rise of temperature the longevity gets reduced and is ultimately shortest at 40°C at all relative humidities. Humidity effect is much less perceptible although at higher temperature of 30°, 35° and 40°C a decrease from 90% relative humidity brings about a slight shortening in the adult life specially in the case of males and a slight reverse effect is indicated at 20° and 25°C.

(*vi*) *Total life period*

The data regarding the development of different stages of life cycle under different combinations of temperature and humidity are presented above. Taking the average developmental periods of all stages and adding them up, the time taken to complete full life at different temperatures has been calculated. The results are given in Table V.

TABLE V

Temp. °C	Average duration in days				Total (full life)	Calculated value of full life period
	Egg	Larva	Pupa	Adult		
20	6	41.9	9.3	6.4	63.9	63.7
25	4.2	31.2	6.4	5.1	46.9	47.3
30	3.5	28.2	5.8	3.4	40.9	40.3
35	3.4	27.2	5.4	3.3	39.2	39.3

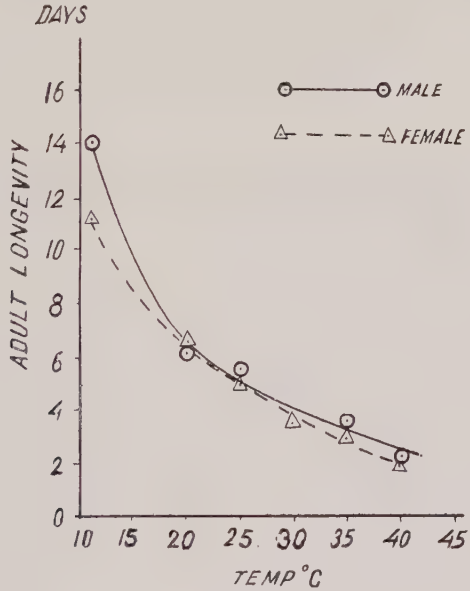

Fig. 4. Adult longevity at different temperatures (average of observations at all humidities studied).

It can be clearly seen from this table that the average duration of full life is longest i.e. 63·9 days at 20°C, 46.9 days at 25°C, 40.9 days at 30°C and shortest i.e. 39.3 days at 35°C. Fig. 5 shows the index of development and the time taken to complete full life from oviposition to adult death at each of the different temperatures.

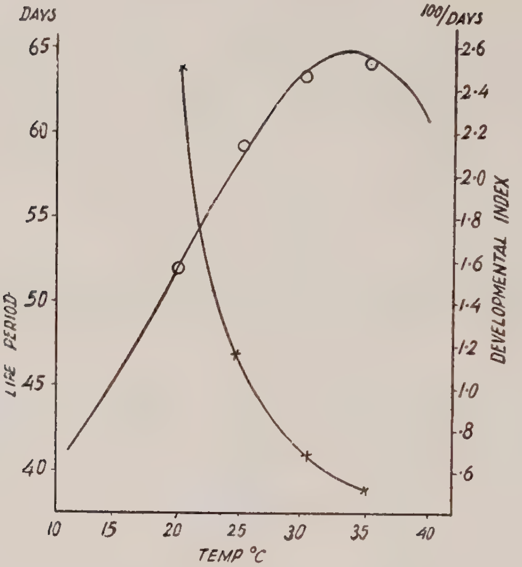

Fig. 5. Full life periods (X) and developmental index (O) at different temperatures

(*vii*) *Biometer*

To the period occupied by full life at different temperatures the following equation (6) has been fitted.

$$Y = 5e^{-0.0008385\,(92.15-t)^2}$$

where Y = developmental index i.e. *195.4/P where P = full life period, t the temperature and e the base of Napierian logarithm. The values of full life period calculated by means of this equation are given in the last column of Table V. The nature of the fit of this equation can also be seen from Fig. 5, in which the smooth curve of developmental index is the one calculated from this equation and superimposed over actual observed data. Further this equation has been used to calculate the temperatures corresponding to different values of developmental index starting from 0.2. These values are given in Table VI and they have been utilized to construct a tentative biometer shown in Fig. 6. This biometer may have to be modified after the same is tested by actual rearing carried out under field conditions of fluctuating temperatures. For detailed explanation of these calculations and the biometer, reference may be made to the first few contributions of the senior author on this subject (5 and 6).

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*Ordinarily the developmental index is calculated as 100/P (as given in figures 1 to 3) but here and in figure 6 it has been taken as 195.4/P to keep the highest value of developmental index as 5.

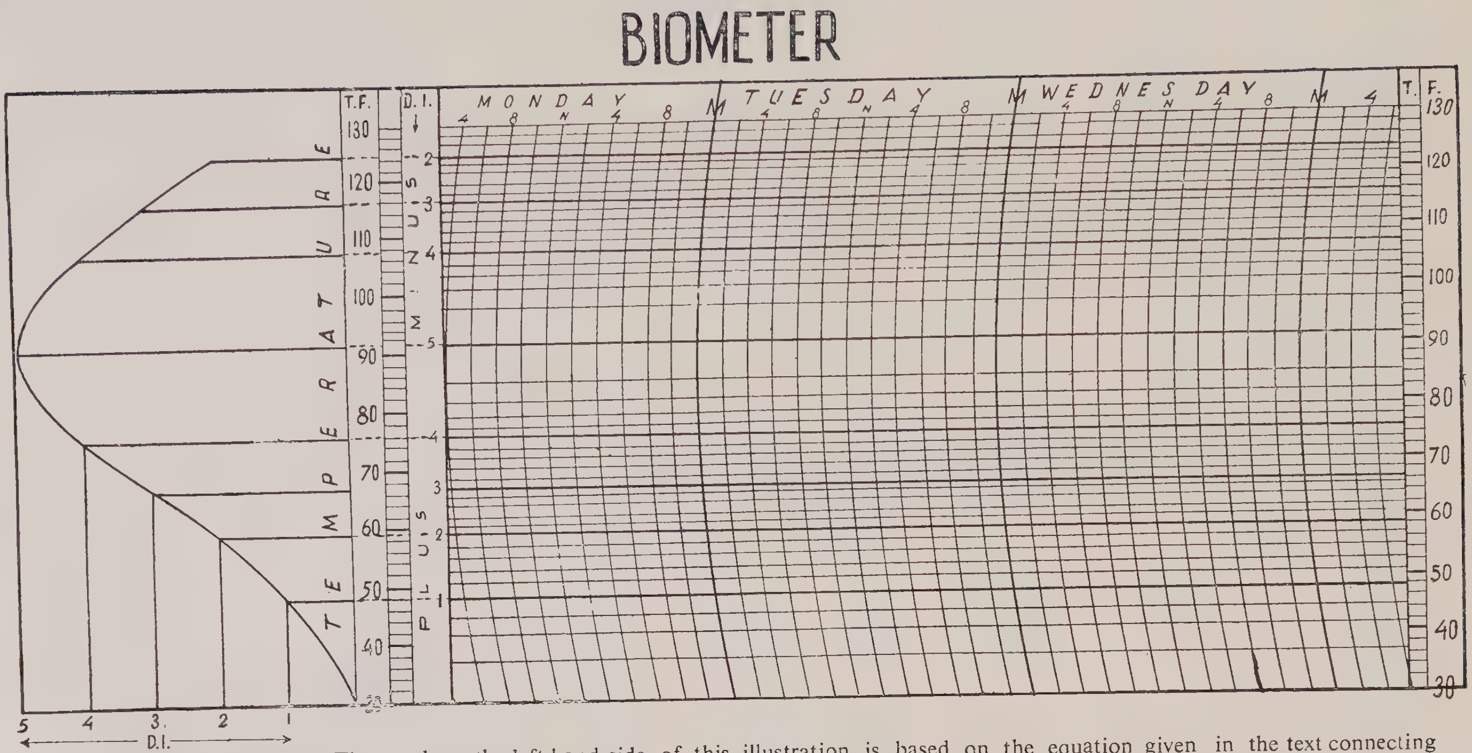

Fig. 6. Biometer: The graph on the left hand side of this illustration is based on the equation given in the text connecting temperature and developmental index (195.4/P) and the right hand portion represents a transparent thermograph chart in which the horizontal lines, instead of showing temperature indicate the calculated rate of development corresponding to different temperatures. When this transparent chart is superimposed over thermograph tracing one can directly read the rate of development at the different points of the time scale.

TABLE VI

CALCULATED VALUES OF TEMPERATURE 't', i.e. (92.15 ± X) CORRESPONDING TO DIFFERENT VALUES OF DEVELOPMENTAL INDEX Y i.e. 195.4/FULL LIFE PERIOD

Y	±X	't', i.e. (92.15—X)	't', i.e. (92.15+X)
0.2	61.95	30.20	154.10
0.4	54.89	37.26	147.04
0.6	50.28	41.87	142.43
0.8	46.76	45.39	138.91
1.0	43.81	48.34	135.96
1.2	41.26	50.89	133.41
1.4	38.95	53.20	131.10
1.6	36.86	55.29	129.01
1.8	34.90	57.25	127.05
2.0	33.06	59.09	125.21
2.2	31.29	60.86	123.44
2.4	29.59	62.56	121.74
2.6	27.93	64.22	120.08
2.8	26.29	65.86	118.44
3.0	24.68	67.47	116.83
3.2	23.08	69.07	115.23
3.4	21.44	70.71	113.59
3.6	19.79	72.36	111.94
3.8	18.09	74.06	110.24
4.0	16.31	75.84	108.46
4.2	14.43	77.72	106.58
4.4	12.34	79.81	104.49
4.6	9.97	82.18	102.12
4.8	6.99	85.16	99.14
5.0	0.00	92.15	92.15

SUMMARY

This contribution reports the following results of investigations on the development of *Chilotraea infuscatellus* Snell under different combinations of temperature (12,20,25,30,35 and 40°C) and humidity (30, 60 and 90%) under laboratory conditions.

1. The larvae of *C. infuscatellus* enter into a physiological diapause during winter in Northern India ; some larvae collected from nature during that period were kept at constant temperatures of 25, 30 and 35°C and most of them failed to regain normal activity and development despite these favourable temperatures.

2. The duration of development of different stages decreases with the rise of temperature and 12°C and 40°C appear to be very near the lower and upper limits for development of the egg, larva and pupa. Percentage viability is lowered at both the extremes of temperature.

3. Best humidity for development of eggs and pupae is 90% at which highest number of individuals completed development under most of the temperature conditions studied. Lower humidities reduce the percentage viability of these stages.

4. The following equation has been fitted to the values of full life periods:

$$Y=5e^{-0.0008385\,(92.15-t)^2}$$

wherein Y represents the developmental index (195.4/P), t the temperature, e the base of Napierain logarithm, and P the full life period. A tentative biometer has been prepared on the basis of this equation.

ACKNOWLEDGMENT

We take this opportunity of recording our gratitude to Dr. B. P. Pal Director, I.A.R.I. and Dr. E. S. Narayanan, Head of the Division of Entomology for providing us the facilities necessary for carrying out these investigations.

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DISCUSSION

Dr. H S. Pruthi observed that since the borers were living inside the cane where humidity was nearly 100% it was hardly much use trying to assess the influence of varying degree of humidity on them.

In the absence of the authors the following paper was taken as read.

Paper

ASSESSMENT OF LOSS DUE TO *CHILOTRAEA INFUSCATELLUS* SNELL IN SUGARCANE

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INTRODUCTION

Chilotraea infuscatellus Snell is a major pest of sugarcane causing severe damage in the early stages of growth, as early shoot borer. After cane formation also some damage is caused by this borer, when it is known as an internodal borer.

Work done so far on the assessment of loss due to *Chilotraea infuscatellus* Snell, has been expressed in terms of percentage mortality of shoots, and percentage loss in weight at the time of harvest. Ingram (1950) estimated the loss due to *Chilotraea infuscatellus* Snell as an early shoot borer as 8—30% and Gupta (1953) recorded the mortality of shoots as 20—50% in Punjab, 6—7% in Bombay, 17—21% in Madras and 42 —47% in Hyderabad.

Loss in weight of attacked cane due to the incidence of *Chilotraea infuscatellus* Snell, as an internodal borer, has been recorded as 7% at Shahjahanpur and 14% at Gorakhpur by Uttar Pradesh workers (1950). Gupta (1953) records the loss as 0.18 to 0.25% in Bihar and 3.3% in Punjab. Isaac (1940) mentions the loss as 11.54% ± 1.627. A reduction of 2.95 units of sucrose has been recorded by Pruthi and Narayan (1939).

None of the workers has so far classified the canes into its various categories of Mother shoots and Primary, Secondary and Tertiary tillers while assessing the loss due to *Chilotraea infuscatellus* Snell as an early shoot borer and as an internodal borer.

In the present paper an attempt has been made to assess the loss occurring in cane due to *Chilotraea infuscatellus* Snell (a) as an early shoot borer and (b) as an internodal borer, after classifying the shoots into (1) Mother shoots (2) Primary tillers (3) Secondary tillers and (4) Tertiary tillers. An assessment of this nature gives a full account of the loss caused to cane at various stages of growth by *Chilotraea infuscatellus* Snell, in the field.

MATERIAL AND METHODS

The results given in this paper are from the experiments conducted at Agricultural Research Station, Rudroor, in Nizamabad district of Hyderabad State, during the years 1950-51 to 1953-54. The variety under trial was Co. 419 being the most predominant variety in the State in general and in the locality in particular. The layout consisted of 8 plots of 50′ × 40′ with 17 rows, 3′ apart, per plot. 35 three budded setts were planted per row during the month of December. The last two rows on either side of each plot were left out for border effect. Of the 13 remaining rows 4 rows in each plot were randomised and in each row, leaving 6′ at either ends for border effect, a random 11′ unit was fixed. Germination counts were recorded in the randomised rows of all the plots from the fourth week after planting at weekly intervals till the 8th week, by which time germination was taken to be complete. All the shoots emerging from the eye buds in the randomised 11′ units were labelled as Mother shoots. The tillers emerging from the Mother shoots were classified and labelled separately into Primary, Secondary and Tertiary tillers. Of these (a) Primary tillers were those that emerged within 8 to 12 weeks after planting, (b) Seconday tillers were those that emerged within 12 to 16 weeks after planting and (c) Tertiary tillers were those that emerged 16 weeks after planting.

The number and class of tillers resulting in mortality due to *Chilotraea infuscatellus* Snell, as an early shoot borer were recorded till harvest at weekly intervals, as some of the late Tertiary tillers grow up to August.

To assess the loss to cane due to *Chilotraea infuscatellus* Snell, as an internodal borer, the canes at the time of harvest in each of the four randomised 11′ units in each of the 8 plots were harvested separately and on the basis of the labels classified into (1) Mother shoots (2) Primary tillers (3) Secondary tillers and (4) Tertiary tillers. In each of these types a further classification was done into (a) Healthy cane and (b) Stem-bored or internodal bored cane. Thus 8 groups of canes were obtained from each randomised 11′ unit. The number of canes and the weight of each cane in each of the 8 groups were recorded. From the difference in weight of healthy and borer affected canes in each of the four types of shoots the loss in weight of cane was determined (vide Table VI). The 8 groups of canes were crushed separately, the sucrose percentage was determined by Polariscope and the deterioration in sucrose percentage as a result of internodal borer attack was calculated (vide Table VII).

RESULTS

(a) 57.5% of Mother shoots, 6.4% of Primary tillers, 27.1% of Secondary tillers and 75.6% of Tertiary tillers were completely killed by *Chilotraea infuscatellus* Snell, (as early shoot borer) during the stand of the crop (vide Table I).

(b) At the time of harvest, during the year 1953-54, 60% of Mother shoots, 43.3% of Primary tillers, 52.6% of Secondary tillers and 35.0% of Tertiary tillers were found to be attacked by *Chilotraea infuscatellus* Snell, (as an internodal borer). (vide Table II).

(c) In all the four classes of shoots, weight per cane of the healthy and borer attacked cane was determined and the loss in weight as a result of attack by *Chilotraea infuscatellus* Snell, (as internodal borer) was found to be 5.1% in Mother shoots, 5.3% in Primary tillers, 11.8% in Secondary tillers and 6.7% in Tertiary tillers. (vide Table III).

TABLE I

PRODUCTION OF SHOOTS AND MORTALITY DUE TO CHILOTRAEA INFUSCATELLUS SNELL, (IN 32 ELEVEN FEET UNITS) DURING THE PERIOD 1950-51 TO 1953-54

Sl.	Year	Mother Shoots		Primary Tillers		Secondary Tillers		Tertiary Tillers	
No.		Total	Mortality	Total	Mortality	Total	Mortality	Total	Mortality
1	2	3	4	5	6	7	8	9	10
1.	1950-51	525	301	488	30	350	115	612	439
2.	1951-52	493	240	592	38	423	105	559	423
3.	1952-53	474	264	585	30	327	93	576	445
4.	1953-54	476	327	575	46	408	95	545	425
Total		1968	1132	2240	144	1508	408	2292	1732
Average		492	283	560	36	377	102	573	433
Percentage of mortality		57.5%		6.4%		27.1%		75.6%	

TABLE II

PERCENTAGE OF INCIDENCE OF INTERNODAL BORER IN THE DIFFERENT GROUPS OF CANE AS OBSERVED AT HARVEST DURING 1953-54

Plot No.	Mother Shoots		Primary Tillers		Secondary Tillers		Tertiary Tillers	
	% of healthy shoots	% of attacked shoots	% of healthy shoots	% of attacked shoots	% of healthy shoots	% of attacked shoots	% of healthy shoots	% of attacked shoots
1	2	3	4	5	6	7	8	9
1.	36.8	63.2	75.0	25.0	42.9	57.1	100.0	—
2.	30.4	69.6	—	100.0	—	100.0	33.3	66.7
3.	42.9	57.1	80.0	20.0	41.7	58.3	100.0	—
4.	38.9	61.1	75.0	25.0	100.0	—	50.0	50.0
5.	42.1	57.9	50.0	50.0	66.7	33.3	66.7	33.3
6.	16.7	83.8	33.3	66.7	25.0	75.0	50.0	50.0
7.	53.8	46.2	57.1	42.9	40.0	60.0	50.0	50.0
8.	58.3	41.7	83.3	16.7	62.5	37.5	70.0	30.0
Average	40.0	60.0	56.7	43.3	47.4	52.6	65.0	35.0

TABLE III

AVERAGE WEIGHT PER CANE OF HEALTHY AND STEM BORER ATTACKED CANES IN EACH OF THE FOUR TYPES OF SHOOTS AT HARVEST DURING THE YEAR 1953-54

	Mother Shoots				Primary Tillers				Secondary Tillers				Tertiary Tillers			
	Healthy		Attacked		Healthy		Attacked		Healthy		Attacked		Healthy		Attacked	
Plot No.	No. of canes	Weight per cane	No. of canes	Weight per cane	No. of canes	Weight per cane	No. of canes	Weight per cane	No. of canes	Weight per cane	No. of canes	Weight per cane	No. of canes	Weight per cane	No. of canes	Weight per cane
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1.	15	41	17	38	12	34	12	33	12	30	13	29	14	18	12	16
2.	17	38	19	37	14	41	13	36	13	35	13	33	15	12	12	12
3.	16	38	19	35	13	39	12	38	12	32	12	28	14	14	13	12
4.	15	34	16	32	13	36	13	34	12	33	13	30	14	16	11	13
5.	18	40	22	38	14	40	15	37	13	36	15	31	17	14	13	13
6.	19	43	23	42	14	38	14	38	12	38	14	29	16	17	12	18
Total canes	100		116		80		79		74		80		90		73	
Average weight per cane Ozs.		39		37		38		36		34		30		15		14
S.E.			± 0.14				±0.9				± 1.48				± 0.9	
Loss in weight due to borer attack			Significant 5.1 %				Significant 5.3%				Not Significant 11.8%				Significant 6.7%	

(d) The juice analysis of healthy and attacked canes showed that the loss in sucrose in affected canes was 6.6% in Mother shoots, 6.6% in Primary tillers, 7.9% in Secondary tillers and 9.1% in Tertiary tillers. (vide Table IV).

DISCUSSION

Chilotraea infuscatellus Snell does more damage to cane when occurring as an early shoot borer before cane formation in the crop, than as an internodal borer after cane formation. As early shoot borer before cane formation, it damages central shoot resulting in the drying up of the central shoot forming a whip-like structure called ' Dead-heart.' This dead-heart invariably results in the mortality of the shoot.

It is seen, from Table I, that 57.5 % of Mother shoots, 6.4% of Primary tillers, 27.1% of Secondary tillers and 75.6% of Tertiary tillers were killed by *Chilotraea infuscatellus* Snell, as early shoot borer, whereas without the classification of shoots the total mortality of shoots was only 42.7%, a fact reported up to 1952-53 as detailed below:—

LOSS DUE TO MORTALITY OF SHOOTS CAUSED BY *CHILOTRAEA INFUSCATELLUS* SNELL, AS AN EARLY SHOOT BORER

Particulars	Mother shoots	Tillers Primary	Tillers Secondary	Tillers Tertiary	Total shoots
1. No. of shoots produced in 32 eleven feet units (vide Table I.)	492	560	377	573	2002
2. No. of shoots mortality due to *Chilotraea*, as an early shoot borer (vide Table I.)	283	36	102	433	854
3. Percentage mortality of shoots	57·5	6.4	27.1	75.6	42.7

After the cane formation, *Chilotraea infuscatellus* Snell larvae bore tunnells into the cane, whereby the vigour of the cane is retarded resulting in loss in weight of cane. The percentage incidence of the internodal borer in the different categories of canes at harvest was 60% in Mother shoots, 43.3 % in Primary tillers, 52.6% in Secondary tillers and 35.0% in Tertiary tillers (vide Table II) and the loss in weight of cane due to *Chilotraea infuscatellus* Snell, as an internodal borer was 5.1% in Mother shoots, 5.3 % in Primary tillers, 11.8 % in Secondary tillers and 6.7% in Tertiary tillers (vide Table III). The number of internodal borer attacked canes in each of the four types of shoots recorded in each plot from the randomised 11′ units at the time of harvest is presented in Table V.

TABLE IV

SUCROSE PERCENTAGE AND BRIX OF HEALTHY AND INTERNODAL BORER ATTACKED CANES IN EACH OF THE FOUR TYPES OF SHOOTS AT HARVEST DURING THE YEAR 1953-54

	Mother Shoots				Primary Tillers				Secondary Tillers				Tertiary Tillers			
Sl. No.	Healthy		Borer attacked		Healthy		Borer attacked		Healthy		Borer attacked		Healthy		Borer attacked	
	Brix %	Sucrose %	Brix %	Sucrose %	Brix %	Sucrose %	Brix %	Sucrose %	Brix %	Sucrose %	Brix %	Sucrose %	Brix %	Sucrose %	Brix %	Sucrose %
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1.	19.73	18.64	18.54	17.43	18.36	17.25	17.70	16.19	17.72	16.40	17.31	15.11	16.98	14.58	15.49	13.58
2.	19.56	18.37	18.27	17.10	18.20	17.09	17.62	16.12	17.53	15.98	16.94	15.02	15.24	13.23	14.42	12.07
3.	21.02	19.42	19.60	18.13	19.32	17.65	17.78	16.27	17.92	16.87	17.42	15.23	17.02	14.76	15.16	13.20
4.	20.46	19.14	19.14	17.93	17.92	16.89	17.40	15.74	17.79	16.75	17.53	15.42	17.07	14.87	15.73	13.36
Avg.	20.19	18.89	18.89	17.65	18.45	17.22	17.63	16.08	17.74	16.50	17.30	15.20	16.58	14.36	15.11	13.05
Loss in sucrose due to borer attack		6.6%				6.6%				7.9%				9.1%		

TALBE V

NO. OF INTERNODAL BORED CANES IN EACH OF THE FOUR TYPES OF SHOOTS RECORDED AT HARVEST DURING 1953-54

Plot No.	Mother Shoots		Tillers	
		Primary	Secondary	Tertiary
1.	9	8	10	—
2.	19	37	13	10
3.	14	7	8	—
4.	18	8	—	10
5.	19	19	7	8
6.	23	22	15	8
7.	10	17	9	9
8.	11	7	4	6
Total from 8 plots or 32 11′ units.	123	125	66	51

The total loss of commercial cane sugar per acre due to the internodal borer has been evaluated, from the data given in Tables III to V, to be 250.13 lbs. as shown below in Table VI.

TABLE VI

LOSS IN WEIGHT OF CANE AS A RESULT OF INTERNODAL BORER ATTACK AFTER CANE FORMATION

Particulars	Mother Shoots		Tillers	
		Primary	Secondary	Tertiary
1. No. of borer affected shoots at harvest (Table V)	123	125	66	51
2. Average weight of healthy canes (Table III)	lbs. ozs. 2 7	lbs. ozs. 2 6	lbs. ozs. 2 2	lbs. ozs. 0 15
3. Average weight of borer attacked canes (Table III)	2 5	2 4	1 14	0 14
4. Average loss in weight per cane due to borer attack	0 2	0 2	0 4	0 1
5. Loss in weight of cane from 32 eleven feet units (1) × (4)	15 6	15 10	16 10	3 3
6. Loss in weight of cane per acre $(5)\times\frac{1320}{32}$	628	644—9	685—13	131—8
7. Average sucrose% of healthy cane (Table IV)	18.89	17.22	16.50	14.36
8. Average Brix of healthy cane (Table IV)	20.19	18.45	17.74	16.58
9. Loss in terms of commercial cane sugar using the formula C.C.S. = [S-(B-S) 0.4] 0.73 × yield in tons per acre. where S = Sucrose of healthy cane B = Brix of healthy cane and C.C.S. = commercial cane sugar	lbs. ozs. 85—10	lbs. ozs. 79—0	lbs. ozs. 80—10	lbs. ozs. 5—9
Total = 250.13 lbs. = O.112 tons				

The deterioration in juice quality in the canes affected by *Chilotraea infuscatellus* Snell, as an internodal borer was due to the fermentation of juices in the tunnelled region. The same has been reported by Luis Mortorella (1954) in his study on *Diatraea saccharalis* Fabr. The deterioration was not the same in all the four categories of canes. It ranged from 6.6% in Mother shoots to 9.1% in Tertiary tillers (vide Table IV). Loss in terms of commercial cane sugar (C.C.S.) per acre due to deterioration in juice quality of affected canes as a result of the attack of *Chilotraea infuscatellus* Snell, as an internodal borer, amounted to 0.127 tons of C.C.S., as evaluated in Table VII.

TABLE VII

DETERIORATION IN JUICE QUALITY AS A RESULT OF INTERNODAL BORER ATTACK, AFTER CANE FORMATION

	Mother Shoots		Tillers					
			Primary		Secondary		Tertiary	
1. Average sucrose% of healthy canes (Table IV)	18.89		17.22		16.50		14.36	
2. Average sucrose % of borer attacked cane (Table IV)	17.65		16.08		15.20		13.05	
3. Weight of borer attacked canes in 32 eleven feet units	lbs. 284	ozs. 7	lbs. 281	ozs. 4	lbs. 123	ozs. 12	lbs. 44	ozs. 10
4. Weight of borer attacked canes per acre (3) $\times \frac{1320}{32}$	11733	1	11601	9	5104	11	1840	13
5. Brix of healthy cane (Table IV)	20.19		18.45		17.74		16.58	
6. Brix of borer attacked cane (Table IV)	18.89		17.63		17.30		15.11	
7. Total C.C.S. that would have been produced if the canes were healthy using the formula, C.C.S.=[S-(B-S) 0.4] 0.73 × yield in tons per acre where S=Sucrose% of healthy cane B=Brix of healthy cane	lbs. 1563	ozs. 6	lbs. 1422	ozs. 13	lbs. 596	ozs. 4	lbs. 180	ozs. 15
8. Total C.C.S. produced from stem borer attacked cane using the formula, C.C.S.=[S-(B-S) 0.4] 0.73 × yield in tons per acre where S=Sucrose% of borer attacked cane B=Brix of borer attacked cane	1468	15	1309	4	535	0	164	4
9. Loss in C.C.S. due to stem borer attack (7-8)	94	7	113	9	61	4	16	11

Total=lbs. 285-15=0.127 tons.

It is evident, from the above discussion that more damage is caused to mother shoots and tertiary tillers by *Chilotraea infuscatellus* Snell (as early shoot borer), while the primary tillers are less affected.

Due to the attack of *Chilotraea infuscatellus* Snell as an internodal borer, the loss occurring as a result of loss in weight of cane is 0.112 tons of commercial cane sugar per acre, costing about Rs. 100/- at the present prices, and the loss due to deterioration in juice quality is 0.127 tons of commercial cane sugar per acre, costing about Rs. 120/-.

CONCLUSIONS

(1) 57.5% of Mother shoots, 6.4% of Primary tillers, 27.1% of Secondary tillers and 75.6% of Tertiary tillers were lost due to *Chilotraea infuscatellus* Snell, as an early shoot borer.

(2) 0.112 tons of commercial cane sugar per acre was the loss as a result of loss in weight of affected canes and 0.127 tons of commercial cane sugar per acre due to the deterioration in juice quality in affected canes, caused by *Chilotraea infuscatellus* Snell, as an internodal borer.

SUMMARY

An assessment of loss to sugarcane by *Chilotraea infuscatellus* as an early shoot borer and an internodal borer has been made separately after classifying the shoots into Mother shoots, Primary, Secondary and Tertiary tillers. *Chilotraea infuscatellus* Snell (a) as an early shoot borer destroys 57.5% Mother shoots, 75% Tertiary tillers, 27.1% Secondary and 6.4% Primary tillers and (b) as an internodal borer it causes a loss of 0.239 tons of commercial cane sugar per acre.

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DISCUSSION

Mr. Girdhari Lal stated that he also had noticed lower mortality in mother tillers, while those produced later showed higher mortality due to the attack of borers. The loss in weight also was found to be greater in later tillers.

Mr. L. N. Nigam pointed out that the percentage of mortality in shoots had been based on the total number of shoots present in the stools, irrespective of the fact whether the shoots were healthy or affected by borers. Normally, the number of shoots in an absolutely healthy stool may be different from that in the affected ones. The percentage could, therefore, be more appropriately worked out on the basis of the number of shoots produced in stools free from pests.

Mr. S.V. Joseph Doss then presented the following paper.

Paper

INCIDENCE OF SUGARCANE BORERS IN NELLIKUPPAM FACTORY ZONE, SOUTH ARCOT, MADRAS STATE

S.V. Joseph Doss
E. I. D. & S. F. Ltd., Nellikuppam, India

In 1953-54 season a thorough study of the incidence of the three common borers, *Chilotraea infuscatellus* (Early Shoot Borer), *Scirpophaga nivella* (Top Borer) and *Proceras indicus* (Internode Borer), prevalent in the factory zone of the E.I.D. & S.F. Ltd., was undertaken in cane planted in various months.

The variety taken up for study was Co. 527. One cent of cane, consisting of 4 rows, was planted in each of the months of February, March, April, May, June and July. One row of cane in each month's planting was taken up for detailed study. Fortnightly observations were recorded from the time of germination upto harvest and the life history of all the shoots that emerged in that one row of cane was traced until harvest. At the end of twelve months after planting, the cane was harvested, classified into various groups according to the age, type of infestation etc. and subjected to a laboratory mill test.

CHILOTRAEA INFUSCATELLUS (EARLY SHOOT BORER)

(A) Mortality of shoots due to *Chilotraea* infestation was as follows.

TABLE I

Month of planting	Percentage Mortality due to *Chilotraea infuscatellus* among shoots that emerged in the 1st month after planting	2nd month after planting	3rd month after planting	4th month after planting	5th month after planting	Total % mortality due to *Chilotraea infuscatellus*
February	4.88	7.55	29.03	*	*	13.71
March	11.76	23.47	**	20.00	—	20.07
April	37.50	26.88	17.86	*	*	26.80
May	57.14	20.59	5.88	—	—	21.55
June	61.54	8.51	0.95	—	*	6.57
July	16.57	2.55	*	*	*	8.27

* All shoots that emerged died due to lagging or other causes.
** Shoots did not emerge.

(B) The percentage mortality among shoots that emerged in the first month after planting increased as the planting season advanced until June.

There was practically no infestation in shoots that emrged in the 4th and 5th months after planting. But it should be noted that, irrespective of the month of planting, the number of shoots produced in the 4th and 5th month after planting was very low as compared to the number produced in the first three months.

(C) The figures indicate that the peak activity of the borer was from the beginning of April to the end of June.

But for the heavy rains received at the end of June it is very likely that the first month's shoots of July-planted cane and 2nd month's shoots of June-planted cane and 3rd month's shoots of May-planted cane would have also recorded higher percentage mortality.

During the period of peak activity, therefore, the following classes of shoots were badly infested :

TABLE II

Month of planting	Shoots produced in which month (after planting) were infested badly		
	in April	in May	in June
February	3rd month	—	—
March	2nd month	3rd month	4th month
April	1st month	2nd month	3rd month
May	—	1st month	2nd month
June	—	—	1st month

(D) March, April and May-planted canes bore the maximum brunt of infestation.

Between these three month's plantings, April-planted cane suffered more in view of the fact that the shoots produced during the period of peack infestation (shoots of 1st, 2nd and 3rd month after planting) constituted 95.30% of the total shoots produced against 73.84% (shoots of 2nd, 3rd and 4th months) in March-planted cane, and 59.19% (Shoots of 1st and 2nd months) in May-planted cane.

S. Ramchandra Iyer, C. Krishnamoorthy and M. Basheer (1951) reported that there was an indication that the pest was particularly serious in the crop planted in March-April in Madras State.

(E) The total number of shoots produced, the average number of shoots produced per stool, the population of millable canes at harvest and yield are given on Table III. It would be seen that the total number of millable canes per acre (column 5 in Table III) in April and May-planted cane were not appreciably different from those in February and March-planted cane. The ultimate yield of cane per acre in April and May-planted cane compared very favourably with the yield

TABLE III

			At harvest			
Month of planting 1	Total No. of shoots produced per acre 2	Average No. of shoots produced per stool 3	% surviv-ed as mill-able canes 4	Total No. of millable canes 5	Average No. of millable canes per stool 6	Yield of cane per acre (Tons) 7
February	1,19,600	6.80	34.45	40,200	2.34	41.86
March	1,11,600	6.64	35.84	40,000	2.38	34.70
April	1,44,800	4.64	29.28	42,400	1.53	33.19
May	1,39,200	4.30	28.16	39,200	1.21	35.74
June	79,200	9.00	33.84	26,800	3.04	22.10
July	1,59,600	4.75	24.06	38,400	1.14	16.74

in March-planted cane. Contrary to the popular belief, therefore, it appears that, in spite of high *Chilotraea* infestation in April and May-planted cane, it is not uneconomical to plant cane in these months so far as yield of cane is concerned.

(F) *Chilotraea* infestation and *Scirpophaga* infestation in the early shoot stage induced ‘compensative tillering’ as would be seen from Table IV.

S. Ramachandra Iyer, C. Krishnamoorthy and M. Basheer (1951) reported compensative tillering in crop infested by *Chilotraea.*

Compensative tillering has been recorded at Pusa, Muzaffarnagar, etc.

SCIRPOPHAGA NIVELLA (TOP BORER)

(A) *Mortality of shoots* :- Data on mortality of shoots due to *Scirpophaga* are given in Table V.

Mortality in general was greater among canes produced in the first two months after planting, than among canes of later months.

All canes infested upto and inclusive of the 7th month after planting died, with exception (as noted under Table V) of those few canes which, though infested and unfit for milling in themselves, produced millable off-shoots. Canes infested after the 7th month after planting survived as millable canes.

(B) *Infestatiom among millable canes, and total infestation* :—Data are given in Table VI.

Percentage infestation in millable canes was highest in April-planted cane. Average for all months was 17.78%.

Total percentage infestation was approximately between 19 and 20% from February to May-planted canes. Average for all months was 15.06%.

(C) *Period of peak infestation* :—The distribution of the total percentage infestation (figures in column 3 on Table VI) among the various months of growth is given in Table VII.

It would be observed that irrespective of the month of planting, the maximum infestation had occurred between the age of 3 and 6 months. Perhaps this is the age when the crop is most vulnerable for *Scirpophaga* infestation.

TABLE IV

Condition of stools upto and inclusive of the 4th month after planting	Cane planted[in																	
	February			March			April			May			June			July		
	% of stools	Average number of shoots produced per stool	% stools that did not contribute millable canes	% of stools	Average number of shoots produced per stool.	% stools that did not contribute millable canes	% of stools	Average number of shoots produced per stool	% stools that did not contribute millabe canes	% of stools	Average number of shoots produced per stool	% stools that did not contribute millable canes	% of stools	Average number of shoots produced per stool	% stools that did not contribute millable canes	% of stools	Average number of shoots produced per stool	% stools that did not contribute millable canes.
Primary shoot and later shoots healthy	13.95	4.67	—	2.44	13.00	4.88	9.72	3.00	2.78	20.79	2.50	5.19	5.56	5.00	5.56	13.10	2.73	3.57
Primary shoot alone infested but later shoots healthy	2.33	2.00	2.33	—	—	—	5.56	3.00	16.66	6.49	6.00	15.58	27.78	25.00	11.11	9.52	5.25	9.52
Later shoots alone infested but primary shoot healthy	60.47	8.12	—	53.66	7.41	—	26.39	7.95	—	9.09	6.29	—	11.11	13.50	—	34.53	7.07	8.34
Primary as well as later shoots infested.	18.60	9.63	2.33	34.15	8.23	4.88	26.39	8.95	13.50	32.47	8.00	10.39	33.33	19.00	5.56	9.52	7.38	11.90

TABLE V

PERCENTAGE MORTALITY OF CANE DUE TO *SCIRPOPHAGA* INFESTATION

Time of Planting	First month after planting		Second month after planting		Third month after planting		Fourth month after planting		Fifth month after planting		Total
	No. of canes emerged	Mortality %	No. of canes emerged	Mortality %	No. of canes emerged	Mortality %	No. of canes emerged	Mortality %	No. of canes emerged	Mortality %	Mortality %
February	16,400	14.63	63,600	19.50	37,200	5.38	2,000	*	400	—	14.05
March	27,200	29.41	78,400	7.14	—	—	4,000	*	2,000	—	12.19
April	25,600	18.75	1,01,200	7.90	11,200	—	1,600	*	5,200	15.38	9.39
May	28,000	14.29	54,400	17.65	47,600	10.92	3,200	12.50	6,000	—	13.79
June	5,200	—	18,800	10.64	42,000	4.76	11,200	3.57	2,000	*	5.56
July	70,000	2,86	62,800	1.27	18,800	*	7,200	*	800	*	1.75
Average	28,733	12.36	63,200	10.13	26,133	5.86	4,867	2.73	2,733	4.87	9.34

* All the canes that emerged died due to lagging or other causes.

N.B.—Percentage mortality figures include canes destroyed by the borer either in the shoot or in the cane stage. They do not include canes which, although themselves destroyed by the borer, contained millable off-shoots at the time of harvest.

TABLE VI

Month of planting	% infestation in millable cane	Total % infestation *
February	15.53	19.40
March	22.00	20.07
April	32.07	18.78
May	21.42	19.83
June	10.45	9.09
July	5.21	3.17
Average	17.78	15.06

This also indicates that the moth prefers young crops to older ones, and generally migrates from older crops—crops more than 6 months old—to younger crops irrespective of the season. This is also substantiated by the fact that there was absolutely no infestation in the months of January to May of the year following the year of planting. The total absence of infestation in the experimental cane may, however, be nearly accidental as slight fresh infestation has been observed in the general crop at the time of harvest.

The large area of new young crop that comes into existence through adsali-planting (July—August) and through the plantings from December onwards evidently attracts the moths away from the older crops which approach harvest between January and June.

The borer has been reported to be at its peak activity[4] between July and December in Punjab, between August and October in Uttar Pradesh, between July and November in Bihar.

(D) *Quality of infested Cane* :- Results of analysis done at the age of 12 months, the normal period of harvest, showed that canes infested at the age of 9 months and less were considerably poorer in quality than healthy canes. Canes which were infested at the age of 10 and 12 months, however, did not suffer much in quality and compared favourably with the healthy canes.

Canes infested by *Scirpophaga and Proceras*, both borers infesting the same stalk, showed the same trend in respect of quality.

Canes infested by *Scirpophaga* at the age of 9 months and less were considerably poorer in quality than canes infested at the same age by *Proceras*. Between canes infested at the age of 10 to 12 months, the difference in quality was less marked.

In the Uttar Pradesh and Bihar[2], *Scirpophaga* was found to cause greater deterioration in quality than the internode borer.

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* Percentage of canes infested and dead + canes infested and alive to the total number of canes that emerged.

TABLE VII

SCIRPOPHAGA—DISTRIBUTION OF THE TOTAL INFESTATION (FIGURES IN COLUMN 3 OF TABLE VI) AMONG THE VARIOUS MONTHS OF GROWTH

Month of growth	Months of planting											
	February 1953		March 1953		April 1953		May 1953		June 1953		July 1953	
	Age in months	Distribution of Infestation %	Age in months o	Distribu- - n %	Age in months	Distribution of Infestati... %	Age in m...ths	Distribution of In-...ion %	Age in months	Distribution of Infestation %	Age in mo..t..s	Distribution of Infestation %
February 1953	1	Nil	*	*		*		*		*		*
March ,,	2	3.85	1	1.67		*		*		*		*
April ,,	3	34.62	2	8.33	1	Nil		*		*		*
May ,,	4	26.90	3	33.33	2	14.08	1	Nil		*		*
June ,,	5	3.85	4	5.00	3	5.63	2	8.70	1	Nil		*
July ,,	6	9,62	5	13.33	4	38.03	3	26.09	2	Nil	1	Nil
August ,,	7	5.77	6	10.00	5	7.04	4	10.14	3	35.00	2	7.69
September ,,	8	3.85	7	11.67	6	23.94	5	33.83	4	35.00	3	Nil
October ,,	9	3.85	8	3.33	7	2.82	6	5.80	5	10.00	4	Nil
November ,,	10	5.77	9	5.00	8	4.23	7	14.49	6	20.00	5	76.92
December ,,	11	1.92	10	8.33	9	4.23	8	1.45	7	Nil	6	15.38
January 1954	12	Nil	11	Nil	10	Nil	9	Nil	8	Nil	7	Nil
February ,,		*	12	Nil	11	Nil	10	Nil	9	Nil	8	Nil
March ,,		*		*	12	Nil	11	Nil	10	Nil	9	Nil
April ,,		*		*		*	12	Nil	11	Nil	10	Nil
May ,,		*		*		*		*		*		*
Total		100.00		100.00		100.00		100.00		100.00		100.00

* Crop not existent.

PROCERAS INDICUS (INTERNODE BORER)

(A) *Degree of infestation* :- The infestation worked out on the total number of shoots produced and the infestation in the millable canes alone are shown in Table VIII.

TABLE VIII

Month of planting	% total infestation (of cane infested and dead + cane infested and alive as millable cane, to total shoots produced)	% infestation in millable canes alone		Total infestation in millable cane (3+4)
		Proceras alone	*Proceras* + *Scirpophaga*	
February	15.05	31.07	3.88	34.95
March	15.41	29.00	3.00	32.00
April	4.42	9.43	3.77	13.20
May	8.33	21.43	7.14	28.57
June	6.57	11.93	5.97	17.90
July	11.03	42.71	2.08	44.79
Average	10.14	24.26	4.31	28.57

The average 'total infestation', worked out on total number of shoots produced (Col. 2), was 10.14%.

The average 'total infestation' in millable canes alone (Col.5) was 28.57%. A survey done in the ryots' crop in general revealed an infestation of 48.94%. The infestation in the experimental plot was presumably low due to :

(1) the frequent movement of the staff in the field which should have disturbed the moths.

(2) the periodical removal of cane trash which was done with a view to facilitating observations, but which should have disturbed the larvae.

(B) *Percentage of internodes affected by the borer* :—The counts revealed that :-

(1) on the average there were 24.33 internodes in a cane stalk.

(2) only 5.43% in the internodes was affected which worked out to 1.33 internode per stalk.

(C) *Distribution of total infestation among the various months of growth or age-group* :- The distribution is shown in Table IX.

It was observed that the borer was present in the cane crop throughout the year.

Infestation generally commenced when a crop was 3 month old, irrespective of the month of planting, and continued almost until the crop was harvested.

The peak infestation, however, occurred in the months of August, September and October irrespective of the month of planting (in July-planted cane alone

TABLE IX

PROCERAS—SHOWING DISTRIBUTION OF TOTAL INFESTATION** IN THE VARIOUS MONTHS OF GROWTH OR VARIOUS AGE-GROUPS

Months of Infestation	Months of planting											
	February 1953		March		April		May		June		July	
	Age in month	Distribution of Infestation %	Age in month	Distribution of Infestation %	Age in month	Distribution of Infestation %	Age in month	Distribution of Infestation %	Age in month	Distribution of Infestation %	Age in month	Distribution of Infestation %
February 1953	1	Nil		*		*		*		*		*
March ,,	2	Nil	1	Nil	1	*		*		*		*
April ,,	3	Nil	2	Nil	2	Nil		*		*		*
May ,,	4	4.44	3	16.28	3	Nil	1	Nil		*		*
June ,,	5	2.22	4	9.30	4	Nil	2	Nil	1	Nil		*
July ,,	6	4.44	5	Nil	5	Nil	3	3.45	2	Nil	1	Nil
August ,,	7	33.33	6	30.23	6	56.25	4	13.79	3	23.08	2	2.27
September ,,	8	13.33	7	13.95	7	6.25	5	6.90	4	15.38	3	Nil
October ,,	9	35.56	8	25.58	8	31.25	6	51.72	5	53.85	4	2.27
November ,,	10	4.44	9	4.65	9	6.25	7	13.79	6	7.69	5	29.55
December ,,	11	2.22	10	Nil	10	Nil	8	10.34	7	Nil	6	11.36
January 1954	12	Nil	11	Nil	11	Nil	9	Nil	8	Nil	7	6.82
February ,,		*	12	Nil	12	Nil	10	Nil	9	Nil	8	40.91
March ,,		*		*		Nil	11	Nil	10	Nil	9	2.27
April ,,		*		*		*	12	Nil	11	Nil	10	Nil
May ,,		*		*		*		*		*	11	4.55
Total		100.00		100.00		100.00		100.00		100.00		100.00

* Crop not existent.

** Figures in column 2 of Table VIII i.e. % canes infested and dead+canes infested and alive to the total number of canes produced.

the maximum infestation was in February i.e. in the 7th month) with the result that in late-planted crops most of the infested canes were of the lower age-group, while in the early-planted crops most of the infested canes were of the older age group.

(D) *Quality of infested cane* :-Results of analyses revealed that unlike canes infested by *Scirpophaga*, canes infested by *Proceras* were not very much inferior in quality to healthy canes in any month of planting.

But as a high percentage of infestation occurred among canes of the lower age-group in the late-planted crops (cane planted in April to July) there was greater loss in weight of cane in late-planted crops than in the early-planted crops. This would naturally result in lower yield of cane in the late-planted crop, if this loss in weight is not compensated for in some other way.

Pruthi and Narayanan (1939)[3] reported that the internode borer was most harmful in respect of quality, the canes attacked by the borer recording 13.07% sucrose against 16.28% of healthy canes.

Ramachandrachari (1951)[4] reported that the loss due to internode borer was more in weight of cane than in the quality of juice.

In Bihar[2], internode borer was found to cause the least loss in yield of cane and sucrose as compared to *Scirpophaga* and the root borer (*Emmalocera* sp.)

BORERS IN GENERAL

(A) *Emergence of shoots* :- The monthwise emergence of shoots expressed as percentage on the total number of shoots produced within 5 months after planting is given in Table X.

TABLE X

Month of planting	% shoots emerged in 1st month after planting	2nd month after planting	3rd month after planting	4th month after planting	5th month after planting	Total	Total No. of shoots per acre	Average No. of shoots per stool
February	13.71	53.18	31.10	1.67	0.33	100,00	1,19,600	6.80
March	24.37	70.25	—	3.58	1.79	100,00	1,11,600	6.64
April	17.68	69.89	7.73	1.10	3.60	100,00	1,44,800	4.64
May	20.11	39.08	34.21	2.29	4.31	100,00	1,39,200	4.30
June	6.57	23.74	53.02	14.14	2.53	100,00	79,200	9.00
July	43.86	39.35	11.78	4.51	0.50	100,00	1,59,600	4.76
Average	22.87	50.29	20.80	3.85	2.18	100,00	1,25,667	5.37

N.B. Shoots produced during the first 5 months after planting have alone been taken into account, as the shoots produced in the later months did not grow into millable canes.

It would be seen that a large majority of the shoots emerged in the first two months after planting, the maximum emergence being in the second month.

TABLE XI

Month of planting	Total Number of shoots produced per acre	% mortality due to						Net available as millable canes	
		Early Shoot Borer	Top Borer	Lagging	Other causes like mechanical injury etc.	Total mortality %	%	Number per acre	Number per stool
February	1,19,600	13.71	14.05	21.40	16.39	65.55	34.45	40,200	2.34
March	1,11,600	20.07	12.19	30.11	1.79	64.16	35.84	40,000	2.38
April	1,44,800	26.80	9.39	32.60	1.93	70.72	29.28	42,400	1.53
May	1,39,200	21.55	13.79	32.47	4.02	71.83	28.16	39,200	1.21
June	79,200	6.57	5.56	53.03	1.01	66.17	33.84	26,800	3.04
July	1,59,600	8.27	1.75	64.92	1.00	75.94	24.06	38,400	1.14
Average	1,25,667	16.83	9.21	39.37	4.44	69.84	30.16	37,833	1.62

Very few shoots emerged in the 4th and 5th months and shoots that emerged after the 5th month did not grow into millable canes.

(B) *Mortality due to borers and other causes* :- Mortality due to borers and other causes and the net population of cane available for milling are shown in Table XI.

The average mortality due to *Chilotraea infuscatellus* and *Scirpophaga nivella* was 16.83% and 9.21% respectively.

Mortality due to "lagging" varied from 21.40% to 64.92%, the average being 39.37%.

Mortality due to mechanical injury and other causes was below 2% in four months and the average was 4.44%.

On the average 69.84% of the shoots were killed due to some cause or other and only 30.16% survived as millable canes, the average number of millable canes per shoot being 1.62.

Average population of cane per acre at harvest was only 37,833 against the average of 1,25,667 shoots produced per acre. These millable canes were not all of them healthy. The borer infestation and other damage recorded in them are enumerated in Table XII.

TABLE XII

Month of planting	% infested by Top Borer	% infested by Top Borer + Internode Borer	% infested by Internode Borer	% lagging	% Healthy	% Healthy cane on Total shoots produced
February	11.65	3.88	31.07	0.97	52.43	18.06
March	19.00	3.00	29.00	4.00	45.00	16.13
April	28.30	3.77	9.43	7.55	50.94	14.36
May	14.28	7.14	21.43	5.10	52.04	14.66
June	4.48	5.97	11.93	8.96	68.66	23.23
July	3.13	2.08	42.71	4.17	47.92	11.53
Average	14.21	4.21	24.74	4.91	51.93	15.70

(C) *Borer infestation and other damage in millable cane* :—The percentage of borer infested canes, canes otherwise in healthy, and healthy canes among the millable canes at the time of harvest are shown in Table XII.

Out of the small percentage left over as millable canes, 14.21% were affected by *Scirpophaga nivella*, 24.72% by *Proceras indicus* and 4.21% by both the borers.

4.91% of the canes were thin and lagging at the time of harvest.

On the average only 51.93% of the millable canes were healthy and these healthy canes constituted but 15.70% of the total number of shoots produced. Presumably this percentage will be considerably lower in the general cane crop as it has been observed that the incidence of *Proceras* either alone or in

TABLE XIII

BORER SURVEY IN MILLLABLE CANE IN RYOTS' CROP

Variety	*Scirpophaga* (1) % loss in				*Proceras* (2) % loss in				*Scirpophaga* + *Proceras* (3) % loss in				Borered canes (1+2+3) (4) % loss in			
	% age infestation	Recovery	Yield of cane	Sugar per acre	% age infestation	Recovery	Yield of cane	Sugar per acre	% age infestation	Recovery	Yield of cane	Sugar per acre	% age infestation	Recovery	Yield of cane	Sugar per acre
Co.527-Adsali	6.16	15.56	2.90	3.42	72.70	16.82	4.39	15.87	4.05	33.98	1.60	2.39	82.91	17.33	8.88	21.68
Co.527-Eksali	7.50	11.95	2.57	3.12	44.79	3.60	1.16	2.79	4.15	23.37	1.54	2.13	56.44	5.44	5.27	8.05
Co. 281	7.84	12.98	2.43	3.18	62.63	6.57	4.94	8.70	4.60	20.79	1.40	2.12	75.07	7.81	8.76	14.01
Co.449	5.12	11.32	1.55	2.00	55.65	4.88	5.76	8.24	3.31	24.85	1.41	1.78	64.08	5.99	8.71	11.92
Co.419	6.69	14.15	1.82	2.42	50.09	5.28	4.24	6.62	6.30	27.84	2.60	3.55	63.08	7.61	8.66	12.59
Average	6.63	14.21	2.39	2.96	58.07	10.19	3.09	8.59	4.34	28.49	1.63	2.39	69.04	11.25	7.11	13.94

combination with *Scirpophaga* was considerably lower in the experimental plot as compared to the general crop perhaps due to the constant movement of the field staff and the trashing of cane in the experimental plot.

The enormity of the damage caused by the borers and other agencies are brought out by these details.

STUDIES ON BORER INFESTATION IN MILLABLE CANE OF RYOTS' CROPS IN GENERAL

In addition to detailed study made in the monthy-planted experimental plots the incidence of borer was studied also in the ryots' crops in general i.e. in the millable cane of bulk crop. This study was made in all the varieties grown by the ryots. The results are shown in Table XIII.

(A) *Borer infestation* :—The total borer infestation (column 4 of Table XIII) varied from 56.44% to 82.91%, Co.527 adsali (18 months) cane recording the highest infestation and eksali (12 months) cane the lowest.

On an average for all varieties, 69.04% of the millable canes were infested by borers. Only 30.96% were, therefore, free from borer attack, this percentage, however, not excluding the canes injured through other agencies and canes that were lagging.

(B) *Loss due to borer infestation* :—The percentage loss in recovery varied (column 4 of Table XIII) from 5.44% to 17.33%, percentage loss in yield of cane from 5.27% to 8.88%, and percentage loss in yield of sugar per acre from 8.05% to 21.68%, in all cases Co. 527 adsali (18 months) cane recording the maximum loss and eksali (12 months) the minimum.

On the average for all varieties, the percentage losses in recovery, in yield of cane and yield of sugar per acre, were respectively 11.25%, 7.11%, and 13.94%. Based on these percentage losses, the average recovery, yield of cane per acre and yield of sugar per acre would have been as follows had there been no borer infestation.

	Actual Season 1953-54	Estimated—had there been no borer infestation
1. Average recovery	9.22%	10.39%
2. Average yield of cane tons per acre	28.54	30.72
3. Average yield of sugar tons per acre	2.63	3.06

The assumption of 'no borer infestation' for the above estimation, relates only to millable canes and not to the crop from its early stages. To assess how the yield and quality would be was there no borer infestation from planting to harvest of cane, cane would have to be grown under conditions which would prevent borer infestation but yet permit normal growth and such crop compared with a normal crop exposed to borer infestation.

INCIDENTAL INFORMATION

Quality of primary and later canes :—Most of the primary shoots emerged within 4 weeks after planting. Primary shoots that emerged later were unhealthy and did not grow well.

Tillering occurred after the fourth week after planting.

At the time of harvest, the healthy canes were classified into various groups depending upon their emergence (i.e. canes that emerged in the first month after planting i.e. primary canes, canes produced in the second month and so on) and were analysed. It was observed that primary canes did not consistently record higher quality than later canes, nor did they record higher weight or length than later canes.

(B) *Lagging canes* :—It was observed that on the average 39.37% of the shoots died due to lagging and 4.44% due to mechanical injury and other unknown causes.

Lagging was the factor which caused the maximum mortality among shoots and the number of lagging shoots appeard to be influenced by the cultural operations, mainly by earthing. It appears essential that cultural operations should be studied critically from this angle and a schedule of operations fixed which would minimise or totally prevent lagging and help all shoots grow vigorously into good millable canes.

Some of the lagging canes which survived as millable canes were thin and also of poor weight and quality.

(C) *Millable off-shoots of canes infested by Scirpophaga* :- The population of canes which produced millable off-shoots consequent on *Scirpophaga* infestation was low. The off-shoots were of poor weight and quality as compared to healthy canes.

(*D*) *Arrowing of cane* :—It was observed that February, March and April planted cane arrowed and cane planted in May, June and July did not arrow. The percentage of arrowed canes in February, March and April planted cane was 40.00%, 37.13% and 21.04% respectively.

SUMMARY

26.04% of the shoots died due to *Chilotraea* and *Scirpophaga* infestation, 39.37% due to lagging, and 4.44% due to mechanical injury and other causes, the total mortality being 69.84%.

Out of the 30.16% which survived as millable cane 48.07% was affected by borers and was otherwise unhealthy, and the 51.93% which was healthy constituted but 15.70% of the total shoots produced.

Mortality of young shoots due to *Chilotraea* and *Scirpophaga* induced compensative tillering.

Proceras caused greater loss in weight than in sucrose content. *Scirpophaga* comparatively caused greater loss in sugar.

Scirpophaga is not a minor pest in the tract as it was considered to be till recently.

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4. Ramchandrachari, C. 1951. *Proceedings of the First Biennial Conference of Sugarcane Research Workers* in the Indian Union—Part II-3, 5-7.

DISCUSSION

Mr. B.D. Gupta enquired about the extent of compensation as a result of extra tillering due to borer attack. The author of the paper referred to the figures in the text and stated that there were appreciable compensations.

In the absence of the authors the following paper was taken as read.

Paper

INCIDENCE OF BORER ATTACK IN SEVERAL VARIETIES OF SUGARCANE GROWN IN THE VISWESWARAYA CANAL TRACT, MYSORE STATE

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and
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Studies have been undertaken at intervals by the Division of Entomology to determine the relative susceptibility of different varieties of cane to borer attack. Duing 1939 to 1941 borer incidence on three principal varieties of cane grown in the area was studied throughout the growing period of the cane and with reference to the different months of planting. In order to correlate rind-hardness with susceptibility to borer attack in mature cane, counts of borer-infested canes were taken at harvest in an experimental plot with 4 varieties. In 1951 observations on the susceptibility of young cane to borer attack were made in respect of 14 varieties, and early in 1952, similar studies were made in respect of 16 varieties. Thus a series of observations were made to study whether varieties show any recognizable range of susceptibility (or resistance) to borer attack.

In the first series of observations (1939-1941) three varieties of cane (H.M. 320, Co. 419 and P.O.J. 2878) were planted in randomised blocks with four replications, every month of the planting year. Five shoots were selected at random from every sub-plot from the 2nd to 12th month of age and the number of shoots showing stem and top shoot borer attack were counted separately and their percentages calculated with reference to the total number of shoots. The seasonal-varietal incidence of the two kinds of borers was thus worked out. A considerable mass of data has accumulated during this period. As the purpose of this paper is only to indicate the maximum rate of infestation and the month (and age of crop) in which it was seen in respect of the varieties under examination, only the relevant information is furnished (Table I).

TABLE I

SHOWING THE AGE (AND MONTH) AT WHICH THE HIGHEST INCIDENCE OF BORER-ATTACK WAS NOTICED IN CANE- VARIETIES PLANTED IN DIFFERENT MONTHS

Variety	Planting Month	Maximum borer-attack observed					
		Stem borer			Top shoot borer		
		Age of Crop	Month	Percentage	Age of Crop	Month	Percentage
H.M. 320	January	6 months	July	7.5	8 months	Sept.	13.0
	February	8 ,,	Oct.	18.9	10 ,,	Dec.	20.0
	March	4 ,,	July	16.8	10 ,,	Jan.	15.8
	April	2 ,,	June	24.7	6 ,,	Oct.	21.0
	July	3 ,,	Oct.	12.5	4 ,,	Nov.	17.4
	Aug.	3 ,,	Nov.	18.4	11 ,,	July	24.2
	Sept.	9 ,,	June	14.4	10 ,,	July	23.2
	Oct.	9 ,,	July	11.3	9 ,,	July	23.1
	Nov.	4 ,,	Mar.	14.4	5 ,,	April	17.9
	Dec.	5 ,,	May	9.9	11 ,,	Nov.	22.1
Co. 419	January	10 ,,	Nov.	11.1	9 ,,	Oct.	15.6
	February	12 ,,	Feb.	13.6	8 ,,	Oct.	12.8
	March	11 ,,	Feb.	16.1	11 ,,	Feb.	12.9
	April	2 ,,	June	18.0	5 ,,	Sept.	14.4
	July	5 ,,	Dec.	19.5	6 ,,	Jan.	21.0
	Aug.	4 ,,	Dec.	10.8	3 ,,	Nov.	22.2
	Sept.	10 ,,	July	12.1	11 ,,	Aug.	21.8
	Oct.	11 ,,	Sept.	4.6	10 ,,	Aug.	22.4
	Nov.	4 ,,	Mar.	19.6	9 ,,	Aug.	16.4
	Dec.	11 ,,	Nov.	9.3	5 ,,	May	18.0
P.O.J. 2878	January	4 ,,	May	9.9	9 ,,	Oct.	13.4
	February	8 ,,	Sept.	10.0	8 ,,	Sept.	15.2
	March	2 ,,	May	8.4	7 ,,	Oct.	16.8
	April	9 ,,	Jan.	8.1	5 ,,	Sept.	9.9
	July	3 ,,	Oct.	16.3	6 ,,	Jan.	19.7
	Aug.	10 ,,	June	11.1	11 ,,	July	13.0
	Sept.	10 ,,	July	8.2	7 ,,	April	20.3
	Oct.	9 ,,	July	7.7	9 ,,	July	14.4
	Nov.	11 ,,	Oct.	9.8	5 ,,	April	18.1
	Dec.	10 ,,	Oct.	9.6	10 ,,	Oct.	16.0

(i) Incidence of both stem and top shoot borers continues throughout the period of growth.

(ii) While the stem borer is normally regarded as a serious pest in the early stages of the crop, the peak of its incidence is reached in an advanced stage in some months' planting ; similarly the top shoot borer is considered as seriously affecting cane in the later stages of growth, but maximum attack can be fairly early.

(iii) The total quantum of attack by the top shoot borer is greater than that of the stem borer in all the three varieties studied.

(iv) Generally, the stem borer incidence is higher in summer planting and top shoot borer in monsoon and post-monsoon planting.

(v) An indication of the peak incidence of the two categories of borers appearing at different stages of the crop is also discernable.

Of the three varieties tested, H.M. 320 appears to be the most susceptible to both the borers and each considered separately, Co. 419 coming next and P. O. J. 2878 last.

In order to correlate rind-hardness with borer infestation, counts were taken of canes infested with the two kinds of borers separately at harvest time, in an experimental plot in which 4 cane-varieties (H.M. 320, H.M. 607, Co. 419 and P.O.J. 2878) had been planted in four randomised replications, 13 months previously. This plot was planted in March 1939 on V.C. Farm by the Sugarcane Research Section of the department. Each sub-plot was separately harvested and during this process counts of canes showing stem and top shoot borer attack were taken separately and their percentages calculated with reference to the total number of canes harvested. During harvest the rind-hardness of each variety was determined by the Sugarcane Research Section using both the types of apparatus designed by Khanna and Subbanna respectively (1). Rind-hardness was maximum in H.M. 607, with P.O.J. 2878, Co. 419 and H.M. 320 following in the order mentioned irrespective of the apparatus employed. As regards stem borer, H. M. 320 showed maximum attack followed by Co. 419 H.M. 607 and P.O.J. 2878 in descending order. H.M. 320 showed the highest top shoot borer incidence, with H. M. 607 coming next, followed by Co. 419 and P.O.J. 2878. This order of susceptibility is in conformity with the results of the earlier observations of 1939-41. A statistical analysis of this data made by the Sugarcane Research Section showed that while rind-hardness of each variety differed significantly from that of the others, varietal differences in respect of borer attack were not significant. Further, correlation between rind-hardness and borer attack though negative was not significant, suggesting the tendency that canes with greater rind-hardness were attacked to a lesser degree. In the following Table the field data on which these conclusions are based are given.

Borer incidence in 14 varieties of cane planted experimentally by the Sugarcane Research Section at V.C. Farm in October, 1951 was studied at fortnightly intervals upto three months of age. There were four replications of each of the varieties which included I.C., Co., and some H.M. canes. Individual plots were 60′ x 18′ in area, with 11 rows in each plot. At each examination

TABLE II

SHOWING THE RIND-HARDNESS AND PERCENTAGE OF ATTACK BY BORERS OF FOUR VARIETIES OF SUGARCANE

Variety	Rind-hardness		Percentage of attack	
	Subbanna's Apparatus	Khanna's Apparatus	Stem Borer	Top Shoot Borer
H.M. 320	12.56	11.17	17.3	37.6
Co. 419	14.14	12.53	14.4	24.1
P.O.J. 2878	15.25	12.60	10.5	21.6
H.M. 607	17.46	15.77	12.4	26.7

the number of infested plants in each plot was counted separately for the two borers, and its percentage with reference to the total number of plants calculated by counting the number of plants in five rows taken at random, striking the average number per row and multiplying it with the number of rows. The results of these observations are given in Table III.

It is not possible to draw any positive conclusions from these figures except that (1) stem borer attack is substantially higher in young cane than top shoot borer attack, (2) peak of incidence of stem borer in young cane is between 2 and 2½ months of age, coming down in the third month, (3) top shoot borer is progressively on the increase in this peroid though its incidence is as yet insignificant and (4) I.C. 202 and H.M. 320 show the highest degree of attack by stem borer, among these 14 varieties.

Infestation by the two kinds of borers on 16 varieties of young cane, upto 5 months of age was studied in an experimental plot laid out at V.C. Farm by the Sugar Cane Research Section in December 1951. These varieties were planted in three replications in sub-plots each measuring 39′x 21′. Observations were started at the age of one month, and continued once a fortnight upto four months (inclusive) in the case of stem borer, and five months in the case of top shoot borer. At each examination the number of infested shoots was counted row by row in all the plots, while the total number of shoots in each plot was assumed to be a figure arrived at by counting the number of shoots in five rows picked out at random, striking the average per row and multiplying it with the actual number of rows in the plot. The percentages of incidence of the two borers, calculated on the basis of these figures are given in Table IV.

No definite inferences regarding the relative susceptibilities of different varieties to borer attack can be drawn from these data ; except for slight variations, all the varieties under trial show a similar trend. Compared with the figures in Table III, it may be seen that the percentages of stem borer attack are lower, while those of top shoot borer attack are higher than in the earlier planting. This difference can be regarded as a seasonal variation.

TABLE III

INCIDENCE OF BORERS IN YOUNG SUGARCANE (14 VARIETIES)

Variety	Percentage of borer attack at									
	1 month		1½ months		2 months		2½ months		3 months	
	Stem borer	Top Shoot borer	Stem borer	Top Shoot borer	Stem borer	Top Shoot borer	Stem borer	Top Shoot borer	Stem borer	Top Shoot borer
I.C. 202	0.5	—	1.6	—	3.9	1.7	6.3	1.4	3.17	1.52
I.C. 26	1.25	—	0.9	—	3.5	1.3	3.1	0.6	2.52	0.92
I.C. 203	1.2	—	1.3	—	1.6	0.3	3.7	0.9	2.5	0.9
I.C. 29	0.92	—	1.7	—	1.3	0.2	3.1	0.7	2.87	0.97
I.C. 201	1.25	—	1.5	0.5	1.9	1.7	3.97	0.75	2.95	0.95
I.C. 8	0.82	—	1.05	—	2.0	0.6	2.82	0.35	2.6	1.05
I.C. 215	0.42	—	0.6	—	2.02	1.4	3.8	0.9	2.4	0.9
I.C. 31	0.6	—	0.5	—	2.2	1.2	4.42	0.8	2.25	0.95
Co. 417	0.75	—	0.5	—	2.5	0.7	2.75	0.3	2.57	0.67
Co. 419	1.1	—	0.8	—	0.8	0.8	3.0	0.47	2·82	0.67
Co. 421	0.25	—	0.4	—	1.2	0.5	2.05	0.2	2.0	0.6
H.M. 661	0.62	—	1.3	—	2.6	0.3	3.7	1.05	2.75	0.85
H.M. 320	1.7	—	1.3	—	4.5	0.8	3.8	0.72	2.27	1.02
H.M. 647	0.97	—	1.2	0.1	2.6	2.9	2.65	0.62	2.32	0.85

TABLE IV

PERCENTAGE OF BORER ATTACK IN 16 VARIETIES OF YOUNG CANE

Variety	Percentage of borer attack at 1 month		1½ months		2 months		2½ months		3 months		3½ months		4 months		5 months	
	Stem borer	Top Shoot borer	Stem borer	Top Shoot borer	Stem borer	Top Shoot borer	Stem borer	Top Shoot borer	Stem borer	Top Shoot borer	Stem borer	Top Shoot borer	Stem borer	Top Shoot borer	Stem borer	Top Shoot borer
I.C. 219	—	—	0.7	—	0.6	—	0.8	—	1.7	5.9	1.0	6.7	1.7	7.4	4.1	6.6
I.C. 206	—	—	0.3	—	0.3	—	1.0	—	1.5	9.9	1.9	10.0	1.6	6.1	8.3	7.6
I.C. 224	—	—	0.5	—	2.3	—	1.05	—	1.2	6.3	1.4	8.4	1.8	8.3	4.1	4.7
I.C 223	—	—	0.9	—	0.4	—	0.8	0.1	2.1	11.2	1.5	8.7	1.9	12.0	9.5	7.9
I.C. 227	—	—	0.1	—	0.7	—	0.7	—	1.1	6.3	1.1	7.2	1.4	5.3	5.05	10.8
I.C. 225	—	—	0.4	—	0.6	—	0.7	—	2.4	8.2	1.5	7.2	1.6	7.9	8.2	7.5
Co. 637	—	—	0.2	—	0.9	—	1.2	—	1.1	6.9	1.7	9.2	1.3	8.7	7.6	10.1
Co. 623	—	—	0.4	—	0.5	—	0.7	—	1.8	11.5	1.5	10.4	1.4	10.3	4.5	9.4
Co. 636	—	—	—	—	0.9	—	0.6	0.02	0.6	—	1.5	9.9	1.3	6.1	4.5	11.6
Co. 634	—	—	0.3	—	0.8	—	1.07	—	1.6	9.5	1.0	9.2	1.3	6.2	5.2	8.5
Co. 419	—	—	0.6	—	0.7	—	0.8	0.07	1.5	9.7	1.9	8.8	1.3	4.1	4.7	9.3
Co. 263	—	—	0.4	—	1.3	—	1.1	0.07	2.1	8.3	1.8	7.0	1.6	7.1	5.3	6.1
Co. 631	—	—	0.6	—	1.9	—	0.9	0.1	1.6	11.4	1.4	12.6	1.5	11.6	6.0	7.0
H.M 320	—	—	0.1	—	1.01	—	1.0	0.02	1.4	7.6	1.3	8.3	1.9	10.6	8.9	10.8
H.M. 647	—	—	0.6	—	0.8	—	0.7	—	1.7	10.6	1.8	6.9	1.2	6.8	5.9	5.4
H.M. 661	—	—	0.5	—	1.7	—	1.1	0.01	1.9	11.6	1.2	10.0	1.5	7.6	4.7	3.1

From these observations, it may be concluded that there appears to be no basis for arranging the cane-varieties tested, in an order of susceptibility to borer attack, in the earlier stages of growth. In the subsequent period of growth, after cane-formation has begun, a significant difference in susceptibility among different varieties may be observed. In other words, borers do not appear to show preference to any particular variety of cane before *cane-formation*, but after cane has started forming some varieties appear to offer a greater attraction to borers than others. This difference between young shoots previous to the development of cane and the later stages may be explained on general grounds as due to rind-hardness and other physical and chemical factors in growing cane determining its susceptibility to borer attack whereas in the pre-cane-formation stage, these factors do not exist. The role of rind-hardness in determining susceptibility to borer damage (in respect of 4 varieties) appears to be, the greater the rind-hardness the lesser the degree of attack.

ACKNOWLEDGMENTS

Grateful acknowledgments are due to the Sugar Cane Research Officer and the Superintendent, V.C. Farm, for extending facilities for making these observations, to M/S. T.V. Subramaniam and B. Krishnamurti Retd. Government Entomologists for their encouragement and to Mr. N.V. Naidu, Field Assistant and the field staff at Mandya for valuable help rendered in the course of these observations.

SUMMARY

Observations on the relative susceptibility of sugarcane varieties to borer attack have been made from time to time.

The borers appear to show no particular preference for any variety of cane, in the younger stages of growth before cane-formation has begun, but in the subsequent stages, some varieties seem to be more susceptible than others. Such susceptibility may be correlated with rind-hardness.

Both stem-borer and top shoot borer continue to attack sugar cane throughout the period of growth.

REFERENCE

1. Report of work done on the Breeding of Thick Canes in Mysore for the year 1939-40. pp. 1-54.

In the absence of the authors Dr. R. K. Tandon presented the following paper.

Paper

EFFECT OF SOIL TREATMENT WITH CHLORDANE AND BHC ON THE INCIDENCE OF TERMITE AND YIELD OF SUGARCANE

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INTRODUCTION

Sugarcane termite, being a major insect pest, has engaged the attention of the research workers in Uttar Pradesh, as also elsewhere, during the last two decades. In recent years, efforts have mainly been focussed on testing the new chlorinated hydrocarbons against this soil pest. BHC and DDT were the first to be tried under field experiments on termite control. Gupta (1950) determined that the application of 20 lbs. of 5% BHC dust in furrows at the time of sowing afforded adequate relief from termite attack to the cane setts. The same author*, during the course of his preliminary experiments at Shahjahanpur, discovered that dipping the cane setts in 1% chlordane suspension enhanced germination as a result of termite control and increased tillering and crop yield. Chlordane and BHC, as soil insecticides, have been tested in other cane growing countries. Bynum *et al* (1949) reported that in Louisiana 4 lbs. of technical chlordane or 0.8 lbs. gamma isomer of BHC in dust form, applied in furrows on cane setts prevented injury to sugarcane by wire worms and increased cane yield, which was highest in chlordane treated plots. Ralph Mathes *et al* (1952) have found that the application of 2 lbs. and 4 lbs. of technical chlordane in furrows at the time of sowing upped sugarcane yield by 12 and 9 percent respectively in the first year and 23 and 32 percent in the second year. Chlordane remained effective for two years against household termite at Illinois (U.S.A.) by pouring 1% aqueous solution into the soil around a house (Shelford, 1950). The same author reported that 0.25% aqueous chlordane kept a cherry tree free from termite and ants for two years. Fleming (1947) found that, in field test, 10 lbs. chlordane, applied as broadcast, remained effective against Japanese beetle larvae in turf for five months.

Some useful methods for checking termite attack to cane setts at the initial stages of the crop had been determined at Shahjahanpur. The effective and economic control of termite attack to the standing crop yet remained a problem. It was, therefore, considered desirable to study the persistent effect of the high doses of BHC and chlordane, the recognised soil insecticides, on the incidence of termite in the grown-up crop. With this objective, a field experiment was conducted by the authors at Rosa (Shahjahanpur) in autumn-sown crop of 1953-54 season. The two insecticides were applied in soil at the time of sowing both in high and low doses ; chlordane at the rate of 100 lbs. and 15 lbs. of 5 percent dust per acre and BHC at 150 lbs. and 20 lbs. of 5 percent dust per acre. The effect of these insecticides on germination and early tillering has already been reported (Siddiqi and Agarwal 1954). In the present paper, their effect on the postmonsoon incidence of termite and the crop yield obtained at harvest is described.

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* Annual report of the Sugarcane Research Station, Shahjahanpur, 1950-51.

EXPERIMENTAL DETAILS

The experiment was conducted at Carew & Co. Farm, Rosa (Shahjahanpur), in sandy loam soil, known to have fairly high infestation of termite. BHC 5 percent dust at 20 lbs. and 150 lbs. per acre and chlordane 5 percent dust at 15 lbs. and 100 lbs. per acre were applied in furrows over the seed pieces at the time of sowing. Co. S. 321, planted in the last week of September, 1953, was the test crop. The experiment had, in all, five treatments including the control, replicated four times in randomised plots of 1/46.1 acre each. Each plot had uniform seed rate of 360 three budded cane setts. The germination, tiller counts at various stages of crop growth and the crop yield at harvest were recorded on the whole plot basis, while the incidence of termite in the millable canes was determined in one complete row of each plot, which amounted to about 10 percent of the total crop.

RESULTS AND DISCUSSIONS

The assessment of results was made on the basis of comparative germination, early and late tillering millable canes, percentage of termite incidence and final cane yield at harvest under different treatments. The data are presented in Table I.

Germination and early tillering. The detailed data on these items have already been given by the authors in a separate pap er (Siddiqi and Agarwal, 1954) and they have been reproduced here for comparison. As will appear from these figures, the percentage germination under both the low and high doses of chlordane was a little over double of that in the untreated plots, and under the lower dose of BHC just twice of the same. The early tillering, recorded 11 weeks after sowing, was three times under the two doses of chlordane, but only twice in the lower dose of BHC as compared to the control. The higher dose of BHC (150 lbs. of 5 percent dust) had, however, no significant increase either in germination or early tillering.

Late tillering and millable canes. The figures given in Table I (item 3) show that the total tillers recorded in August were significantly higher at 5 percent level under 20 lbs. BHC dose and at 1 percent level in the two doses of chlordane than those in the control. The number of millable canes harvested in December 1954, were also higher under the lower doses of the two insecticides at 5 percent level of significance than in the control, but in the higher dose of chlordane this increase was significant at 1 percent level. This increase in the higher dose of

BHC was, however, not significant over the control. By comparing the figures for early and late tillering, vide Table I item 4, it appears that about 90 percent of the total tillers produced had emerged in the chlordane treated plots under both the doses during the first 11 weeks, while this was about 70 percent in the lower dose of BHC and only 35-40 percent in the control and the high dose of BHC. These observations clearly indicate that chlordane had quickened the tillering, which gave a lead to the crop growth in this treatment.

Incidence of termite and crop yield at harvest :—The termite incidence in the millable canes, recorded at harvest, was least under the high dose of chlordane, though the same under the high dose of BHC and the lower dose of chlordane was also significantly less than in the control plots. Converting the percentage incidence in term of loss in yield, it was established that the untreated crop suffered a loss of only 4.4 percent due to termite attack to the millable canes. These data show that the loss in crop yield due to termite attack to the grown up canes was not very great at Rosa, where the experiment was conducted. The effectiveness of the high dose of chlordane on the postmonsoon attack of termite, due to longer persistence, is however, indicated from these data.

Comparing the crop yield under different treatments, which is the ultimate objective of all insect control, it is observed that the highest increase of 41.5 percent over the yield in the untreated plots was recorded in 100 lbs. dose of 5% chlordane dust. The increase was 27.6 percent in 15 lbs. dose of chlordane and only 16.2 and 3.2 percent in the low and high doses of BHC, respectively.

DISCUSSION

Reviewing the overall results, it is observed that chlordane in both the doses proved effective in checking the termite attack to the seed setts, increasing thereby the germination and also in hastening the tillering and plant growth. The high dose of chlordane reduced also the termite incidence to the millable cane quite significantly. The lower dose of BHC also increased germination and tillering, but this increase was not as high as in the chlordane treated plots. The high dose of BHC displayed deleterious effect on the crop. From these results, it is also indicated that chlordane acted not only as effective insecticide against termite but also stimulated plant growth, which resulted in notably higher yields. Such increase in plant growth due to the application of chlordane in soil have also been reported by workers abroad. Some have attributed this increase in plant growth to the direct stimulation and others to the control of pathological organisms attacking the root system. Compton (1949) considered this apparent plant stimulation due to the control of injurious micro-organism, which usually escape the attention of entomologists, because of the insidious nature of their attack. Whatever may be the cause of the stimulated plant growth, the superiority of the cane crop in the chlordane treated plots of our experiment was too pronounced to be overlooked by even a casual visitor.

TABLE I

EFFECT OF SOIL TREATMENT WITH HIGH AND LOW DOSES OF BHC AND CHLORDANE

Criteria for assessment	BHC 5% dust		Chlordane 5% dust		Control	Critical difference*
	20 lbs. per acre	150 lbs. per acre	15 lbs. per acre	100 lbs. per acre		
1. Germination	46.6%	31.5%	51.9%	52.4%	23.1%	9.98 13.99
2. No. of tillers per acre 11 weeks after sowing (Middle of December, 1953)	48819	25411	67306	62327	20238	23188 32500
3. No. of tillers per acre at the end of Angust, 1954	66280	63329	71581	71028	56887	9496 13369
4. Percentage of total tillers, which were formed during the first 11 weeks	73.7%	40.0%	94.0%	87.7%	35.6%	—
5. No. of millable canes per acre at harvest in December, 1954	54017	48255	54610	60437	45500	7523 10547
6. Percentage incidence of termite at harvest	24.2%	17.5%	15.7%	5.6%	29.0%	7.4 10.4
7. Percentage loss in yield due to termite attack to the millable canes	3.7%	2.7%	2.4%	0.8%	4.4%	Termite attacked canes were less in weight by 15.2% as compared to healthy canes.
8. Average yield in mds. per acre	1078.7	958.3	1184.1	1313.6	928.3	109.6 153.6
9. Increase of acre yield in mds. over control	150.4	30.0	255.8	385.3	—	—
10. Percentage increase in yield over control	16.2%	3.2%	27.6%	41.5%	—	—

*Upper figures represent C.D. at 5 percent level and the lower ones at 1 percent level.

Economic aspect of the treatments:—From the figures of acre-yield obtained under different treatments, it is noted that the increase in yield was 385.3 maunds per acre under 100 lbs. dose and 255.8 mds. under 15 lbs. dose of 5% chlordane dust. The increase in yield was 150.4 mds. per acre in the lower dose of BHC and only 30.0 mds. in its high dose. The cost of 15 lbs. of 5 percent chlordane dust at the present market rate comes to Rs. 6/6/- and that of 100 lbs. Rs. 42/6/-. No doubt the higher dose of chlordane has given an extra yield of about 130 mds. above its lower dose, but considering the poor resources of an average cane grower specially in Northern India it may not be possible for him to invest Rs. 42/6 per acre at the time of sowing, in order to obtain higher yields. On this consideration, the application of the lower dose i.e. 15 lbs. of 5 percent chlordane dust costing Rs. 6/6/- seems to be an economic proposition. The cost of 20 lbs. of 5 percent BHC dust is also low, being Rs. 4/6/- but the return in yield was significantly less in this treatment.

ACKNOWLEDGMENTS

The experiment was conducted at Carew & Co., Rosa (Shahjahanpur). The authors feel grateful to Mr. S.D. Rogers, the Cane Manager, for providing land and other facilities. Grateful thanks are also due to Dr. R.K. Tandon, Director, Sugarcane Research, Shahjahanpur, who kindly took keen interest and offered useful suggestions in the conduct of this experiment.

SUMMARY

The results of soil treatment with high and low doses of chlordane and BHC and their effect on germination, tillering, incidence of termite and ultimate crop yield are given in the paper.

The application of both the high and low doses (100 lbs. and 15 lbs. 5 percent dust) of chlordane in furrows at the time of sowing brought about significant increase in germination, tillering, millable canes and the acre-yield. In BHC treatment, these increases were noticed only in the lower dose (20 lbs. of 5% dust) but they were of lesser order than those of chlordane. It is suggested that the efficiency of chlordane as soil insecticide in giving higher yields may partly be due to the stimulated plant growth under these treatments. The high dose of chlordane (100 lbs. of 5% dust per acre) remained effective against post monsoon attack of termite having an incidence of 5.6 percent against 29.0 percent recorded in the untreated plot. The high dose of BHC (150 lbs. of 5% dust per acre) had an incidence of 17.5 percent, which was equal to the lower dose of chlordane. But the high dose of BHC proved deleterious to the crop.

An extra yield of 385.3 mds. per acre in the high dose of chlordane, costing Rs. 42/6/- and 255.8 mds. in the low dose, costing Rs. 6/6/- was recorded. The increase in the BHC treated plots was 150.4 mds. per acre in the lower dose costing Rs. 4/6/- and only 30.0 mds. in its high dose. To check the termite incidence

at the initial stages of the crop, at places where its post monsoon attack is not very severe, it is suggested that 15 lbs. of 5% chlordane dust, costing Rs. 6/6/- can profitably be applied by an average cane grower.

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DISCUSSION

After concluding the paper, Dr. Tandon wanted to know whether the heavy dosage of chlordane 5% at 100 lbs. of dust per acre had been found by any worker to cause any deleterious effect on the plant growth.

Dr. H.S. Pruthi enquired as to why intermediate dosages between 15 lbs. and 100 lbs. were not taken up for trials. Dr. Tandon replied that the idea of taking up such a heavy dosage was to investigate if it could cause immunity in the crop against termites for a long period.

Mr. C.N. Agarwala stated that in Bihar and Uttar Pradesh, aldrin had proved effective in checking termite attack, but he did not know whether aldrin adversely affected the rate of germination of the buds. Dr. Tandon replied that he had not come across any adverse effect with lower dosages of aldrin.

Mr. P.N. Awasthi enquired about the percentage of termite attack noticed in the experiment. He was referred to item No. 6 of the Table in the paper.

Mr. A.N. Kalra pointed out that the effect on germination should be studied 8 weeks after planting. Dr. Tandon replied that the present paper related to the effect of soil treatment with chlordane and BHC on yield and the effect on germination had been dealt with in earlier papers by the authors.

Mr. K. L. Khanna, presented the following two papers. These were discussed together.

Paper

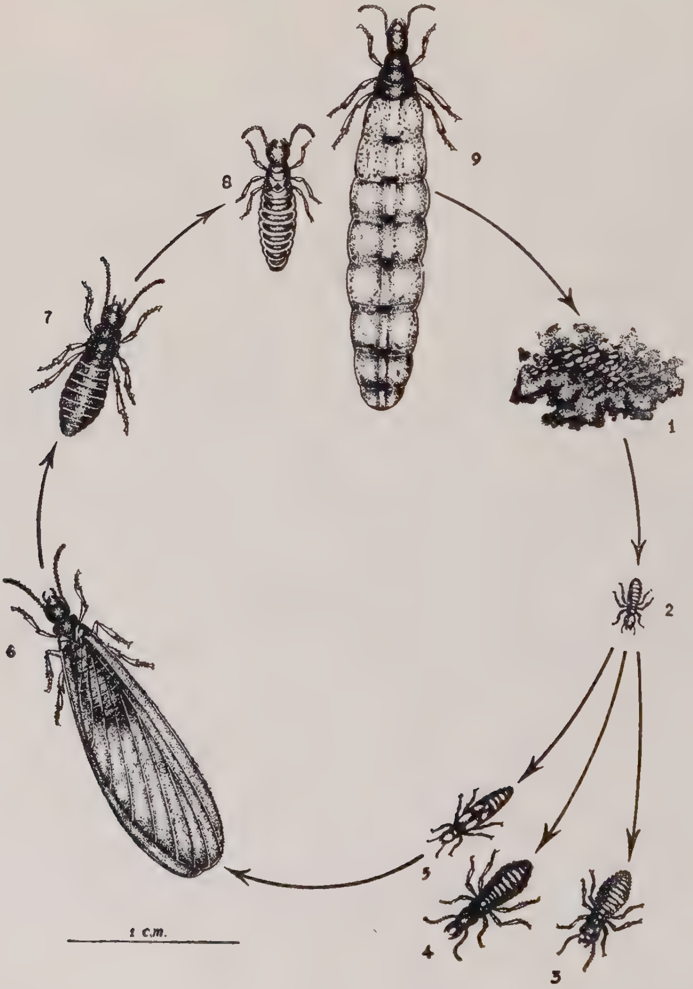
TERMITES INFESTING SUGARCANE AND THEIR CONTROL

K. L. Khanna, L. N. Nigam, S. B. D. Agarwala and D. K. Butani
Central Sugarcane Research Station, Pusa, Bihar, India.

INTRODUCTION

Termites or " white ants " are social insects living in colonies (termiteria); each colony having its Queen, King, Soldiers and Workers (Plate I). These insects

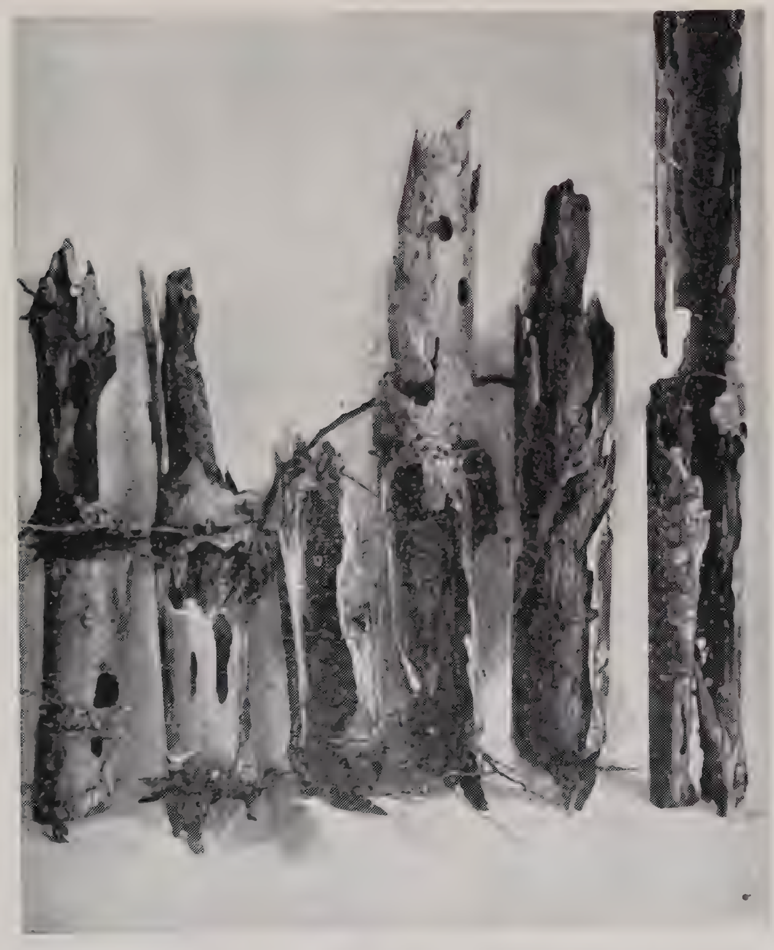
PLATE I



1. EGGS 2. NYMPH 3. WORKER 4. SOLDIER
5. REPRODUCTIVE NYMPH 6. WINGED REPRODUCTIVE
7. REPRODUCTIVE AFTER LOSS OF WINGS 8. KING 9. QUEEN

feed on a vast range of hosts and devour almost anything, sugarcane being no exception. The ravages of this subterranean enemy begin soon after the setts are placed in the soil and in severe cases of infestation, nothing may remain of the sett after a fortnight except a thin papery rind. The termites may attack any point on the sett and the impression, that termites are not able to penetrate the unbroken rind of the cane and can enter the setts only through cut ends, on which was based the practice of coal-tarring the ends of setts, is somewhat erroneous. In hard-rinded varieties, a certain amount of preference is shown for the eye,s root zone and growth regions but, more generally, whatever point on the sett is met with first is attacked. Once they gain access inside the rind,

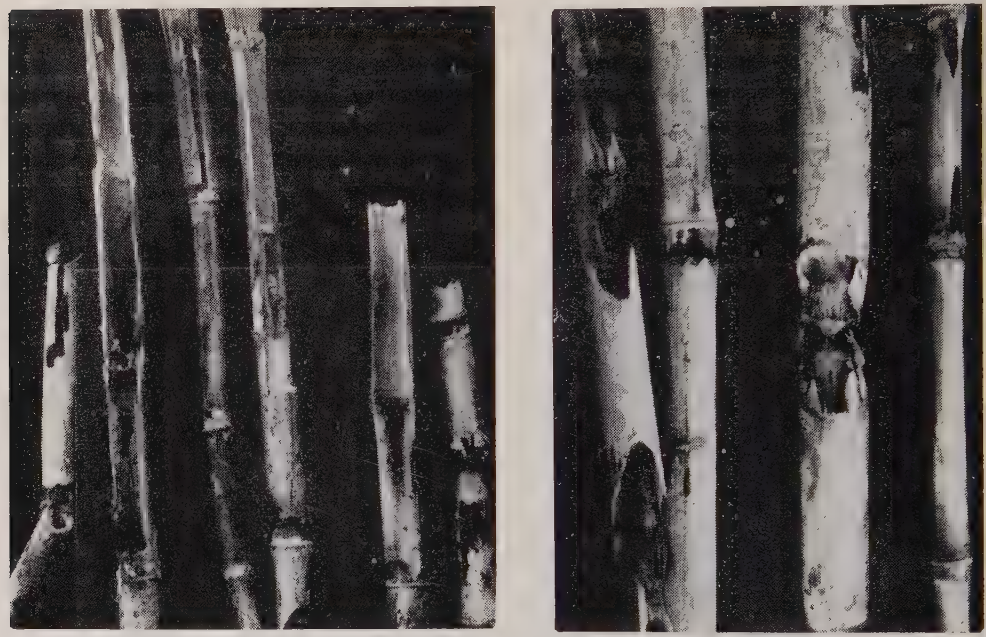
PLATE II-A



Showing varying degrees of damage to cane setts by termities.It is clear that the attack can be at any spot and not necessarily at cut ends and any treatment that only protects the cut ends can hardly be expected to afford protection against the pest.

termites eat the core very rapidly. In the case of new shoots, they first gnaw at the base below ground, gradually eat into the cortex and finally destroy the growing point. An idea of the damage caused by termites can be had from Plates II and III. The shoots thus attacked turn pale and come out with the slightest pull. Liability to attack seems to depend largely on the nature of the soil, incidence and damage being less pronounced in clayey soils as compared to sandy soils. The amount of moisture present in the soil also exerts a considerable influence in this regard and it has been observed that termites thrive best under conditions of bad aeration and poor drainage. Long dry spells make the trouble acute, particularly in areas where the soil runs out of moisture, and although it is generally believed that termites are only active during the dry weather, observations of the present authors appear to suggest a continuous damage throughout the year, except under heavy monsoon conditions.

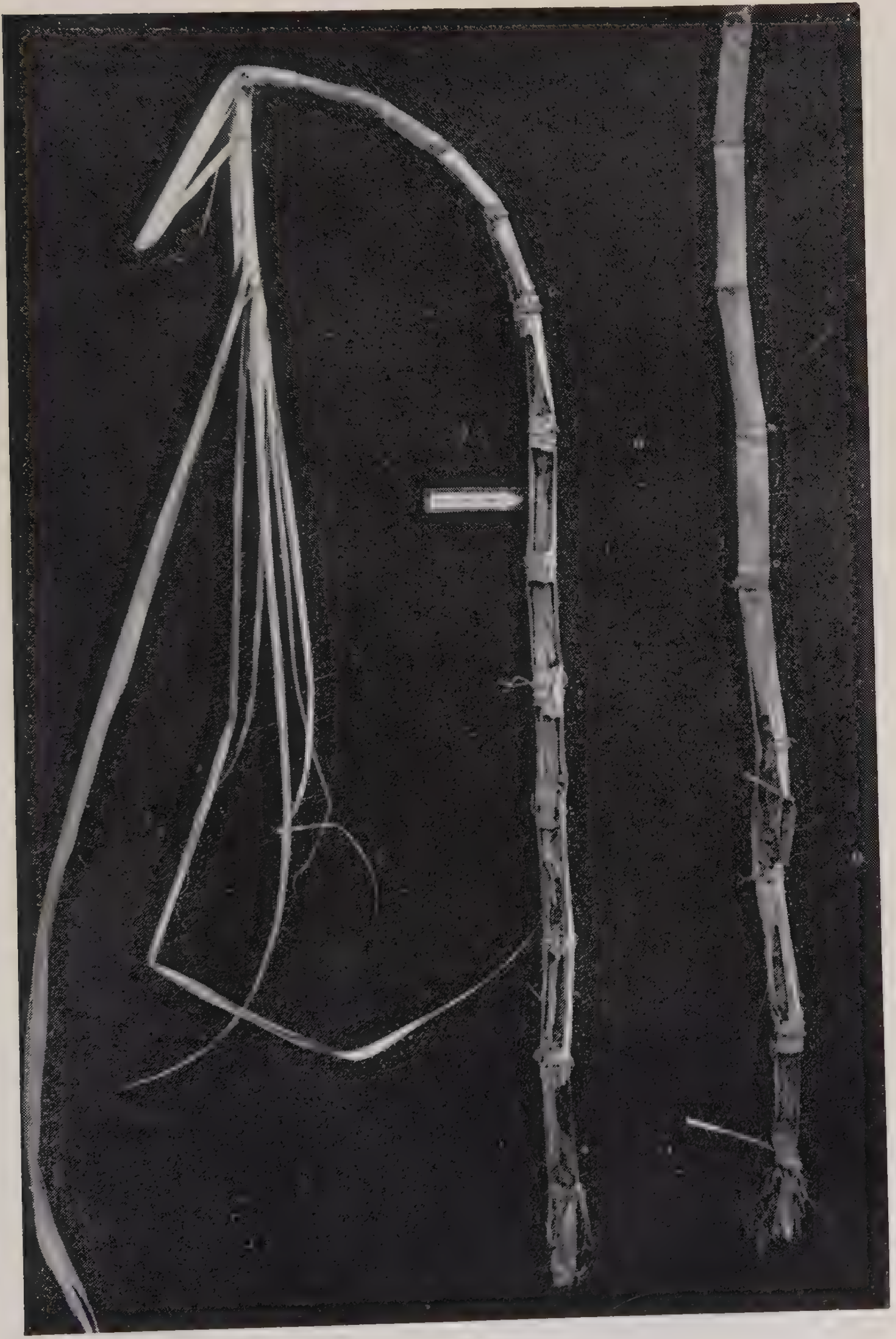
PLATE II-B PLATE II-C



Showing canes damaged by termites. Even the nodes, which are the hardest parts of the rind, are completely eaten away by the pest.

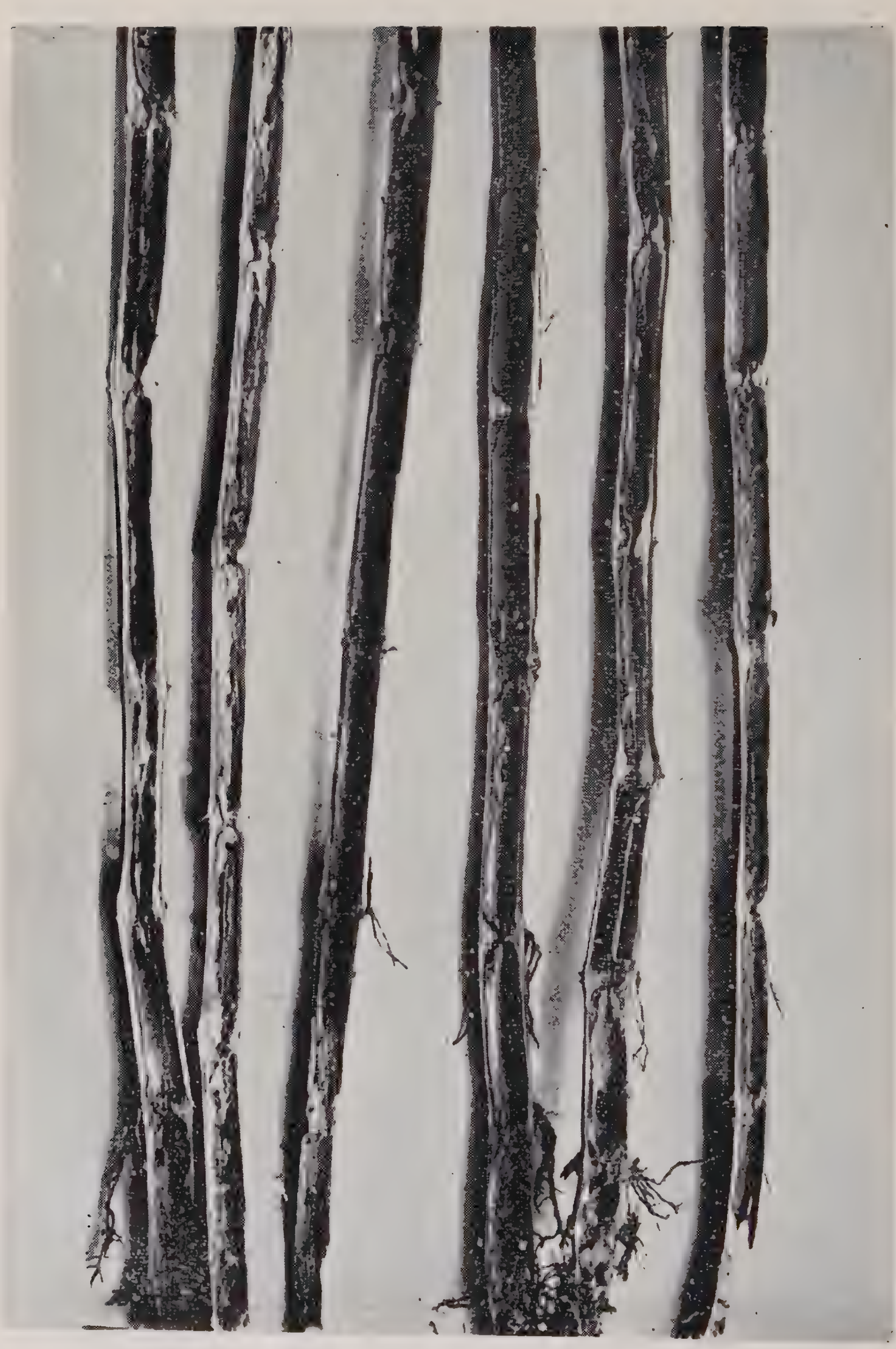
The various species of termites recorded on sugarcane from the various parts of the world, as listed by Box (6) include : *Amitermes herbertensis* Mj., *A. latidens* Mj., *A. obtusidens* Mj., *Coptotermes acinaciformis* Frogg., *Schedorhinotermes seclusus* Hill, *Heterotermes paradoxus* Frogg. and *Mastotermes darwiniensis* Frogg. from Queensland ; *Anoplotermes schwartzi* Banks, *Heterotermes cardini* Snyder, *Nasutiterms costalis* Hlmgr. and *Obtusitermes aequalis* Snyder from Cuba ;

PLATE III-A



Showing damage to standing cane upto two-thirds of the length of the stalk. The entire contents are eaten away: the papery envelope covering the soil brought in by termites.

PLATE III-B



The stalk cut open longitudinally to show the severity of damage.

Capritermes nitobei Shir., *Coptotermes formosanus* Shir., *Reticulitermes speratus* Kolbe. and *Odontotermes formosanus* Shir. from Formosa ; *Coptotermes vastator* Light, *Heterotermes philippinensis* Light, *Microcerotermes losbanosensis* Oshima and *Microtermes gilvus* Hag. from Philippines, the last one also from Java ; *Kalotermes* spp., *Neotermes* sp. and *Nasutitermes costalis* Hlmgr from Barbados, the first one also from Trinidad ; *Nasutitermes corniger* Mots., and *Termes nigritus* Silv. from British Guiana ; *Nasutitermes rippertii* Ramb. from Jamaica ; *Odontotermes classicus* Sj. from Somalia ; *Parvitermes pallidiceps* Banks from Haiti ; and *Reticulitermes flavipes* Kollar from U.S.A. The species recorded so far in India are : *Microtermes obesi* Hlmgr., *Odontotermes assmuthi* Hlmgr., *O. obesus* Ramb., *O. Taprobanes* Wlk. *Trinervitermes* (*Cyclotermes*) *heimi* Wasm. and possibly one other species of *Odontotermes*. These are erratic records of the species, as no regular survey to collect different species damaging agricultural crops in India and to identify them have been conducted and this must be considered to be vital for successful application of control measures.

REVIEW OF LITERATURE

Ghosh (9) tried, at Pusa (Bihar), rosin compounds, naphthalene emulsion, lead arsenate, crude-oil emulsion, fish oil rosin, creosote, Apterite and formalin both for dipping setts as well as mixing the insecticide with earth in the furrows. He found the dipping of setts in lead arsenate solution (1 lb. in 2 gallons of water) to be the best. Lal (16) tried at Gurdaspur (Punjab) lead arsenate, crude-oil emulsion and copper sulphate and got good results with lead arsenate and crude-oil emulsion. Rao (22) tried at Coimbatore (Madras) all the above insecticides in addition to mercury perchloride, tobacco decoction, carbon bisulphide, potassium sulpho-carbonate, potassium xanthogenate, *neem* cake (Azadirachta indica), Bordeaux mixture, tar and Mortant. He got best results by applying potassium sulpho-carbonate with irrigation water. Fletcher (7 and 8) reported that the use of crude-oil emulsion in irrigation water gave maximum protection to the young growing crop.

This method was also suggested by Husain (12) and Issac and Misra (15) as a good temporary protection. Hector (11) found dipping of cut ends of setts in coaltar before planting to prevent termite attack. Subramania Iyer (23) observed that the various repellants, tried in Mysore, were only temporarily effective. Husain (13) pointed out that Paris Green dust used in the proportion of 1: 4 with lime, seriously affected the germination but when used in the proportion of 1: 9 or 1:12, it greatly reduced the infestation of termites without causing any injury to the plants. Gupta (10) suggested the use of properly decomposed manures, frequent irrigations, application of crude-oil emulsion in irrigation water @ 10 lbs. per acre, painting of cane setts, fully or at the cut ends with coaltar, application of *neem* cake @ 0.75 tons per acre, a fortnight before planting, dipping the setts in sodium fluosilicate suspension or bach (*Acorous calamus*) and copper sulphate infusion or lime and lead arsenate solution in water or Clensel or Keto solution in water or phenyl diluted in water or soap and nicotine sulphate solution in water and fumigation of ant-hills with carbon bisulphide. Issac (14) recommended dipping of setts in a suspension of 2% Paris Green and 4% lime, which was later confirmed by Pruthi (18), who further added that setts immersed for 30-60 seconds immediately before planting, in 5% suspension of lead arsenate and cold water remained free from termite attack, while those immersed in 5% sodium fluosilicate began to show signs of attack after a month and those having the ends smeared with coaltar as also untreated setts were damaged after 3 weeks. Narayanan and Rattan Lal (17) conducted experiments with DDT, BHC, Dithane, lead arsenate and Paris Green and observed that the effects of dipping the setts in a mixture of 2% Paris Green with 4% lime as well as of treating the soil in furrows, before planting the setts, with 1.25% DDT emulsion were significant at 1% level. The effect of dipping setts either in 5% DDT solution or 1% lead arsenate with 10% lime or treating the soil in furrows before planting with 0.5% gamma BHC dust were significant at 5% level. Rao (19) observed that 5% BHC dust applied @ 20 lbs. per acre at the time of planting was superior to 5% DDT. Later (20) he conducted pot trials and recorded that, with increasing dosages BHC retarded both shoot growth and root development. This confirmed the earlier findings of Agarwala (1 and 2) at Pusa. Rao (21) also tried methyl bromide and remarked that while the chemical was very effective in eradicating the pest at the source of origin, its utility was doubtful in view of its phytotoxic effects.

WORK DONE IN BIHAR ON TERMITE CONTROL

Work on termites was initiated in Bihar by the Senior author in 1936 and general survey of the State undertaken with a view to finding out the badly infested areas, the time of the year when the pest was most active, the extent of damage caused by the pest and the control measures that were being adopted locally in those areas. The work on control was directed towards (i) testing the efficacy of the local control measures practised in the State and (ii) testing the efficacy of various chemicals available from time to time. In the former were included : dips in *neem* leaf decoction, butter-milk and asofoetida, butter-milk and kerosene emulsion, lime wash, wood ash, coaltar, crude-oil emulsion and traps e.g. use of pitting horse dung, spreading castor leaves, stocking dry mustard plants and embedding mango twigs etc. Under chemicals, the different doses of lead arsenate, Paris Green, sodium arsenate, Bordeux Mixture, Seekay soil fumigant, Clensel, Whiz winter were tried. The local practices did not prove to be of any use and as such were discontinued and all experiments were switched on to the use of various chemicals that were available from time to time. Each chemical was tried repeatedly, before it was finally discarded. In addition to the chemicals mentioned above, others have been tried in more recent years viz., BHC, DDT, parathion, mercuric chloride, chlorinated camphene, copper sulphate, Narsingham's solution (proprietory name of an experimental product), phenyl solution, endrin, aldrin and dieldrin.

Micro-plot experiments as well as field experiments were conducted every year. All the experiments were adequately replicated, there being not less than four replications in any case. The net plot size was 1/40th acre in case of field experiments and 9′ × 6′ or 1/807 acres in case of micro plots. The data collected were statistically analysed and results obtained are shown in Tables I to XIII.

TRIALS, RESULTS AND DISCUSSIONS

Indigenous Methods

Repeated tests with the indigenous methods of control showed that under non-irrigated conditions the value of such treatments was problematical. Although some of them, viz., kerosene and crude-oil emulsions gave satisfactory toxicity values in the laboratory, their efficacy in the field was short-lived, and unless their application could be repeated at close intervals they were not likely to be useful. Besides, kerosene emulsion adversely affected the germinability of eyes. Wood ashes showed no beneficial effect whatsoever. So far as the crude-oil emulsion was concerned, even bi-weekly application with irrigation water did not help in mitigating the trouble. Likewise coaltarring afforded no protection but on the contrary it delayed germination. Even the setts wholly covered with coaltar were not immune to termite attack and within three weeks after planting, these were found as badly damaged as those that were either treated at the cut ends or not treated at all. The traps mentioned above were effective in attracting termites but there was no evidence to show that either the incidence or damage in the crop was significantly lessened.

In repeated experiments with lead arsenate, Paris Green, sodium arsenate, Bordeaux Mixture, Seekay soil fumigant, Clensel, Whiz summer and Whiz winter, each one of these insecticides showed very high toxicity in laboratory tests but in the field most of them failed and the duration of their effective repellance and noxiousness varied from one week to about five weeks. It was found, as a result of population counts, that during this period of 'effectiveness', termites retired into deeper layers of soil and came back only when conditions for movement and attack were favourable again. Seekay soil fumigant failed altogether to prevent termite attack and over 60% of setts were attacked within the first week. The Clensel series was decidedly better but did not appear to be a complete success under unirrigated conditions. Both Clensel concentrated and Whiz summer, however, showed stimulating effects on germination and early growth. Lime (saturated solution) dip proved as efficacious as the Clensel series. Sodium arsenate, Paris Green and lead arsenate were useful upto the end of third week after which the plants were attacked and suffered heavy mortality.

Newer Insecticides

Field Experiment (1946-47) :—Comparative trials with newer insecticides were initiated during 1946-47. In the first year, two different doses of BHC were tried in the field, each under the different methods of application viz., dipping both the cut ends in 2.5% or 7.5% BHC dust or soaking the setts for 4 hours in 0.25% or 0.75% emulsion of BHC. The results obtained (Table I) showed that the soaking of setts in 0.75% BHC emulsion was more effective and resulted in increase in yield by 9.62 tons per acre over control.

TABLE I

EFFECT OF DIFFERENT FORMULATIONS OF BHC ON TERMITES : 1946-47

Criteria		Control	Cut ends dipped in 2.5% BHC dust	Cut ends dipped in 7.5% BHC dust	Soaked for 4 hours in 0.25% BHC emulsion	Soaked for 4 hours in 0.75% BHC emulsion
Germination %		39.24	36.26	35.20	32.00	34.35
Incidence %						
May I	fortnight	8.37	11.08	10.83	10.94	7.89
May II	,,	3.69	13.73	8.18	14.24	8.58
July II	,,	8.45	6.22	3.72	8.05	4.06
August I	,,	17.99	12.42	7.35	28.02	9.99
August II	,,	15.35	9.37	5.85	22.04	4.61
September I	,,	14.88	10.21	10.36	16.82	6.21
September II	,,	19.49	20.87	14.81	17.70	3.59
October I	,,	11.67	21.31	11.69	23.66	8.26
October II	,,	47.21	46.42	31.15	25.34	26.10
November I	,,	53.41	28.42	31.00	39.92	20.43
November II	,,	61.39	33.34	35.24	30.50	30.85
December I	,,*	31.36	38.07	18.16	44.72	15.05
Yield/acre **	(tons)	4.41	4.35	4.10	11.18	14.03

* Significant at 5% level.

**Significant at 1% level.

All percentage figures transformed to $\sin^{-1}\sqrt{p}$.

Field Experiment (1947-48) :—This year BHC was tried in the form of liquid Agrocide-3, 5% BHC (Gammexane D 025), 50% BHC (Gammexane P 520) and technical BHC (Gammexane D 919). The observations (Table II) revealed that soaking of setts for 3 hours in 0.75% BHC emulsion was definitely better than other treatments in checking the attack of termites, but the highest yield was obtained from the plots where the setts were dusted with 5% BHC @ 150 lbs. per acre, being 1.80 tons more per acre than under control.

TABLE II

EFFECT OF DIFFERENT FORMULATIONS OF BHC ON TERMITES : 1947-48

Criteria	Setts dusted with 7.5% BHC	Setts soaked for 3 hrs. in 0.75% BHC emulsion	Setts soaked for 3 hrs. in 2.2% solution of liquid Agrocide-3.	Setts soaked for 3 hrs. in 1.5% of Agrocide-3 Wettable powder	Setts irrigated with 0.5% sol. of BHC. @ 100 gallons/acre	Setts dusted with 5% BHC @150 lbs./acre.	Control
Germination percentage**	33.30	31.95	35.83	24.16	39.59	36.11	36.94
Incidence percentage							
Pre-monsoon*	30.47	22.94	26.06	21.26	16.70	15.84	27.73
-do- Monsoon**	37.68	24.97	36.74	34.59	32.08	29.07	35.67
-do- Postmonsoon**	43.92	51.67	41.21	44.36	61.07	50.71	45.80
-do- Overall*	36.77	30.32	33.18	33.60	37.17	32.65	35.75
Yield/acre **(tons)	1.47	1.75	2.43	1.15	3.50	4.46	2.65

* Significant at 5% level.

** Significant at 1% level.

All percentage figures transformed to $\sin^{-1}\sqrt{p}$

Micro-plot Experiment (1947-48) :—During this year, a micro plot experiment was also conducted with 5% DDT dust @ 82.3 lbs. per acre, 5% BHC dust @ 82.3 lbs. per acre and lead arsenate @ 4 lbs. per acre. After 4 months, the total surviving canes (from all the six replications of each treatment) were 13,98, 23 and 13 in the case of DDT, BHC, lead arsenate and control respectively ; after another two weeks these numbers came down to 3, 35, 21, and 1 cane in the respective treatments. At harvest, the total numbers of canes left were 1, 3, 24 and 0 in the same order of treatments.

Micro-plot Experiment (1948-50) :—The experiment was repeated during the subsequent two years. The results obtained showed that BHC dust was comparatively better as it protected the crop for some time ; during 1949-50, it gave best protection for the first five months : thereafter, lead arsenate showed better results.

Field Experiment (1948-50) :—The field experiments during these two years included the different formulations of BHC. The results (Table III) showed that dusting in open furrows with 5% BHC @ 150 lbs. per acre was better, though the treatment differences were statistically non-significant.

TABLE III

EFFECT OF DIFFERENT FORMULATIONS OF BHC ON TERMITES: 1948-50

Criteria	Year	Setts dusted with 7.5% BHC	Setts watered in furrows with 0.5% BHC. solution 100 galls./acre	Setts dusted in furrows with 5% BHC@ 150 lbs./acre	Control
Germination %	1948-49*	68.43	56.27	59.52	47.89
	1949-50	53.72	57.36	41.79	46.74
Incidence %					
Pre-monsoon	1948-49	17.05	13.42	10.81	16.13
	1949-50*	10.50	7.34	4.98	8.65
-do- Monsoon	1948-49	39.27	38.15	32.30	37.42
	1949-50*	13.53	9.92	5.13	11.56
-do- Postmonsoon	1948-49	37.26	42.77	42.47	40.15
	1949-50	12.87	8.03	6.53	15.81
-do- Overall	1948-49	31.32	30.67	28.95	31.34
	1949-50*	12.62	8.67	5.32	12.98
Yield (tons)/acre.	1948-49	21.75	24.18	23.88	17.72
	1949-50	23.43	22.32	21.81	21.21

* Significant at 5% level.
All percentage figures, transformed to $\sin^{-1}\sqrt{p}$.

Field Experiment (1950-51) : The experiment was repeated this year with a slight modification (additional treatment involving application of 0.5% BHC suspension @ 150 gallons per acre). The results (Table IV) showed that the

TABLE IV

EFFECT OF DIFFERENT FORMULATIONS OF BHC ON TERMITES : 1950-51

Criteria	Setts dusted with 5% BHC @ 150/lbs. acre	Setts dusted with 7.5% BHC @ 80 lbs./acre	Setts watered in furrows with 0.5% BHC solution @ 100gl./ac.	Setts soaked for 3 hrs. in 2.2% liquid Agrocide	Control
Germination percentage*	33.33	54.26	35.71	63.45	44.25
Incidence %					
Premonsoon*	21.32	13.18	9.28	19.59	24.55
-do- Monsoon	45.48	44.75	40.10	43.29	39.03
-do- Post-monsoon	52.80	50.23	45.37	51.33	42.26
-do- Overall	38.47	38.80	36.93	39.77	36.81
Yield/acre (tons)	9.53	13.85	14.41	13.65	10.29

* Significant at 1% level.
All percentage figures transformed to $\sin^{-1}\sqrt{p}$.

best protection was afforded to the setts soaked for 3 hours in 2.2% liquid agrocide-3, while the highest yield and lowest termite infestation were obtained from plots where setts were watered with 0.5% BHC suspension @ 150 gallons per acre. The average period of effective protection provided by the more efficacious treatment was of the order of three months.

Micro-plot Experiment (1950-51) :—An experiment in micro plots was also conducted this year with the object of finding out an effective insecticide along with its suitable dose for controlling the activities of termites in sugarcane fields. The various insecticides included were : Parathion (Rhodiatox), 5% BHC (Gammexane D 025), 50% BHC (Gammexane P 520), liquid Agrocide -3, 5% DDT 100% DDT, lead arsenate and mercuric chloride and the results obtained (Table V) revealed the efficacy of most of the treatments over the control but this lasted only for the first 3½ months, after which period differences were non-significant (Plate IV).

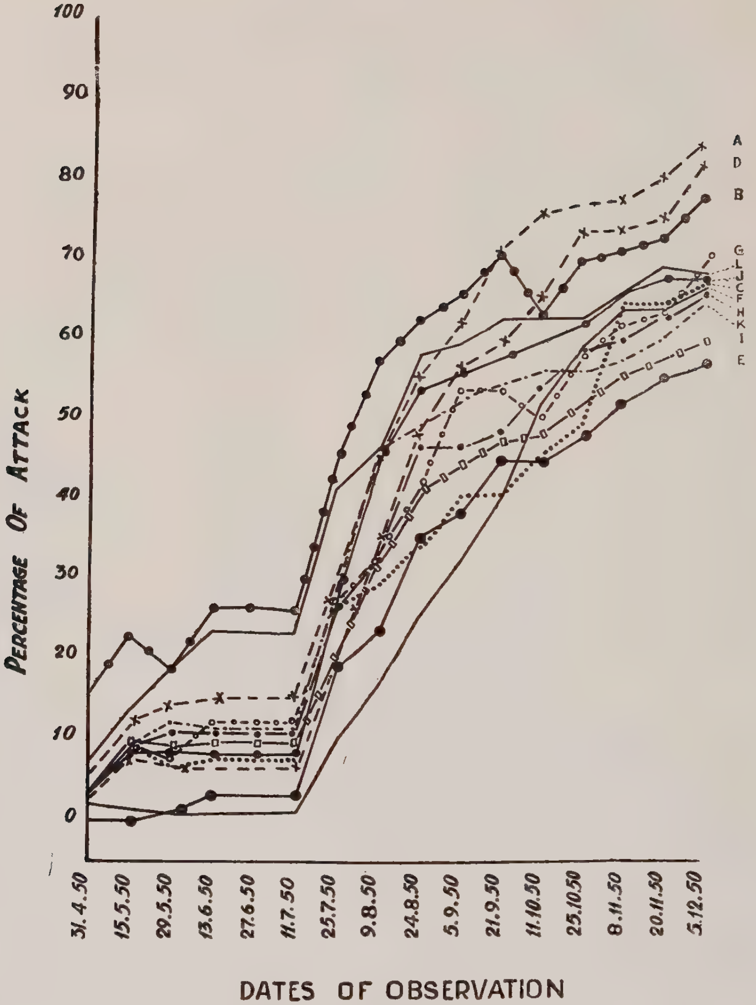
Field Experiment (1951-52) :—In view of the fact, that the above insecticides did not afford protection for the whole year, an experiment was conducted this year, wherein repeated treatments were given using DDT, BHC, parathion (Rhodiatox) and chlorinated camphene (Toxaphene). The results obtained (Table VI) showed that watering of the setts in furrows with 0.5% BHC suspension @ 150 gallons per acre and giving two subsequent irrigations with the same dose and formulation after 3 and 6 months respectively was capable of rendering better protection than any other treatment, but only upto the monsoons. Thereafter the differences between all treatments including control were non-significant. The cost of each treatment came to about Rs. 16/- per acre.

Micro-plot Experiment :—In the micro plot experiment conducted, the insecticides tried were 5% phenyl solution, mixture of 2 ozs. lead arsenate, 20 ozs. lime and 30 lbs. water, parathion liquid, 5% BHC, 50% BHC, copper sulphate, 5% DDT, 5% chlorinated camphene, mixture of 1 lb. lead arsenate and 2 gallons water containing 0.1% gelatine, 0.25% mercuric chloride solution and 0.5% Narsingham's solution. Here also the results obtained (Table VII) showed the superiority of application of 5% BHC dust @ 150 lbs. per acre in furrows, but only for three months, and thereafter differences between all treatments including control were non-significant (Plate V).

Thus the problem still remained unsolved, because if low doses were applied every year or more frequently, toxic concentrations were liable to be built up in the soil in view of the fact that BHC decomposes very slowly in the soil. On the other hand, application even as high as 150 lbs. of 5% BHC per acre did not give materially significant benefits against termites for more than 3 months.

Field Experiments (1952-53) :—Two field experiments and one micro plot experiment were conducted during this year. The insecticides used in the latter were BHC, chlorinated camphene, lead arsenate with lime, aldrin, dieldrin, endrin and Narsingham's solution (Plate VI). In one of the large scale trials only BHC,

PLATE IV



A—Parathion dust @ 50 lbs./acre.
B—Parathion paste @ 8.5 lbs./acre.
C—Parathion liquid @ 5 lbs./acre.
D —7.5 % BHC dust @ 80 lbs./acre.
E—5 % BHC dust @ 150 lbs./acre.
F—0.5 % BHC suspension @ 150 gallons/acre.
G—Soaked in 2.2 % liquid Agrocide-3 for 3 hours.
H—Soaked in 5 % DDT for 15 minutes.
I—Dusted with 100 % DDT.
J—Soaked for 15 minutes in lead arsenate 1 lb. in 2 gallons of water.
K—Soaked in mercuric chloride 0.25 % solution for 15 minutes.
L—Control (Untreated).

TABLE V

EFFECT OF DIFFERENT INSECTICIDES ON TERMITES (MICRO-PLOT EXPERIMENT) : 1950-51

Criteria	Setts dusted with parathion dust @ 50 lbs./acre	Parathion paste @ 8.5 lbs./acre	Parathion liquid @ 5 lbs./acre	Setts dusted with 7.5% BHC dust @ 80 lbs./acre	Setts dusted with 5% BHC dust @ 150 lbs./acre	Setts watered with 0.5% BHC solution @ 150 gallons/acre	Setts soaked in 2.2 % liquid agrocide-3 for 3 hours	Setts soaked in 5% DDT for 15 minutes	Setts dusted with 100%o DDT	Setts soaked for 15 minutes in lead arsenate 1 lb. in 2 gallons of water	Setts soaked in mercuric chlorid 0.25% solution for 15 minutes	Control
Germination %	27.33	27.00	21.67	25.33	22.00	26.67	21.33	27.53	24.33	27.33	29.00	16.00
Incidence % on 31-4-50	16.55	24.21	14.26	12.71	10.64	13.09	14.53	13.05	14.14	13.87	11.35	26.02
15-5-50	22.42	20.49	19.25	14.66	9.13	9.93	18.62	17.73	18.84	19.45	18.10	33.05
29-5-50	24.48	26.74	16.72	16.69	10.31	8.07	18.01	20.82	19.87	11.60	21.62	33.75
13-6-50*	24.89	33.37	17.44	14.01	12.31	8.31	21.84	20.77	20.20	19.95	21.46	38.06
27-6-50*	24.63	32.11	17.27	14.01	11.36	8.31	21.84	20.77	20.20	19.95	21.42	38.06
11-7-50*	24.63	32.11	17.27	14.01	12.20	8.31	21.84	20.77	20.20	19.95	21.42	37.26
25-7-50	33.49	42.55	31.36	23.99	25.06	28.73	31.74	31.77	33.31	35.76	35.96	52.44
9-8-50	44.07	47.35	32.88	36.11	28.12	29.07	37.97	35.17	33.98	48.34	34.81	57.29
24-8-50	50.34	52.89	35.77	45.84	37.01	35.68	43.34	43.57	39.67	55.57	46.65	71.59
5-9-50	52.98	54.14	39.30	50.24	39.84	39.04	50.04	43.62	40.86	56.67	49.28	72.69
21-9-50	56.74	57.73	38.51	53.60	44.91	43.73	50.04	45.26	43.45	58.34	48.43	73.08
11-10-50	62.23	53.81	42.24	58.08	45.34	47.85	46.00	49.90	44.86	63.82	49.15	73.08
25-10-50	62.78	58.59	41.90	68.59	51.99	52.55	50.56	52.38	48.41	64.58	49.34	73.08
8-11-50	62.44	60.72	54.12	68.59	55.42	55.72	58.58	53.48	52.29	68.72	50.18	74.04
20-11-50	64.79	64.75	54.12	69.78	57.00	55.72	59.18	55.19	53.72	73.52	51.77	75.00
5-12-50	68.14	67.56	55.57	73.45	58.44	58.30	61.05	57.99	56.76	73.52	54.02	75.00
Yield/acre (tons)	3.35	5.03	8.50	6.38	11.49	9.23	4.69	10.28	6.78	10.24	6.79	7.32
Sucrose %	17.40	17.84	17.20	17.79	17.39	17.58	17.54	18.93	18.96	18.78	17.34	17.13

All percentage figures transformed to $\sin^{-1}\sqrt{P}$.

*Significant at 5% level.

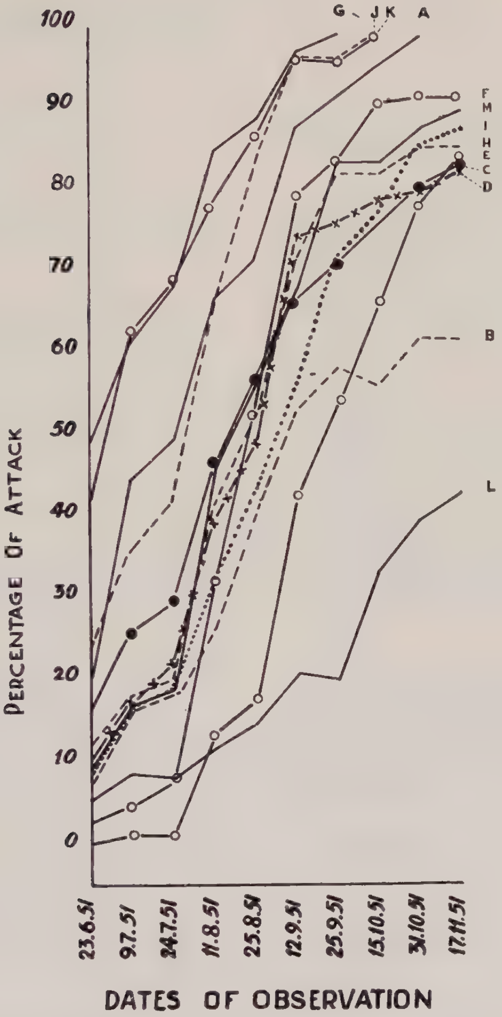
TABLE VI

EFFECT OF DIFFERENT INSECTICIDES ON TERMITES: 1951-52 (FIELD TRIALS)

Criteria	Setts dusted in furrows with 5% DDT @ 300 lbs./acre subsequently irrigated twice (after 3 & 6 months of planting) with 0.5% BHC solution @ 150 gallons per acre	Setts dusted in furrows with 5% DDT @ 300 lbs. per acre	Setts dusted in furrows with 25% chlorinated camphene @ 40 lbs./acre and irrigated twice as in treatment 'A'	Setts dusted in furrows with 25% chlorinated camphene @ 40 lbs./acre	Setts watered in furrows with 0.5% BHC solution @ 150 gallons/acre and subsequently irrigated twice as in treatment 'A'	Setts dusted in furrows with 5% BHC @ 150 lbs./acre and 50% BHC mixed in soil @ 15 lbs./acre and irrigated after 3months	Setts soaked in parathion liquid 0.1% for 15 minutes	Control (untreated)
	A	B	C	D	E	F	G	H
Germination %	22.95	28.10	23.75	25.91	16.41	24.31	25.77	21.50
Incidence % pre-monsoon*	13.60	15.89	12.54	8.11	7.28	8.86	12.17	17.78
-do-monsoon*	20.52	20.53	14.97	19.75	9.92	12.29	25.48	13.95
-do-post-monsoon	47.01	43.30	48.27	49.67	43.67	48.55	55.87	42.88
Incidence % overall	30.93	29.45	28.90	22.60	25.85	28.18	33.33	28.75
Yield/acre (tons)	18.75	12.94	15.37	15.88	12.50	22.42	14.19	11.76

All percentage figures transformed to $\mathrm{Sin}^{-1}\sqrt{P}$.
*Significant at 5 % level.

PLATE V



A—Soaked in 0·5 % phenyl solution for 24 hours before planting.
B—Soaked in a mixture of 2 oz. lead-arsenate, 20 ozs. lime and 30 lbs. water for 24 hours.
C—Parathion liquid in furrows @ 5 lbs./acre.
D—5 % BHC dust @ 20 lbs./acre.
E—5 % BHC dust @ 150 lbs./acre.
F—0·5 % BHC suspension @ 150 gallons/acre.
G—Copper sulphate dust @ 40 lbs./acre.
H—5% DDT @ 300 lbs./acre.
I—5% Chlorinated camphene @ 300 lbs./acre.
J—Soaked in mixture of 1 lb. lead-arsenate and 2 gallons water having 0·1 % gelatine
K—Soaked in 0·25 % mercuric chloride solution for 15 minutes.
L—0·5 % Narsingham's solution @ 100 gallons/acre.
M—Control (untreated).

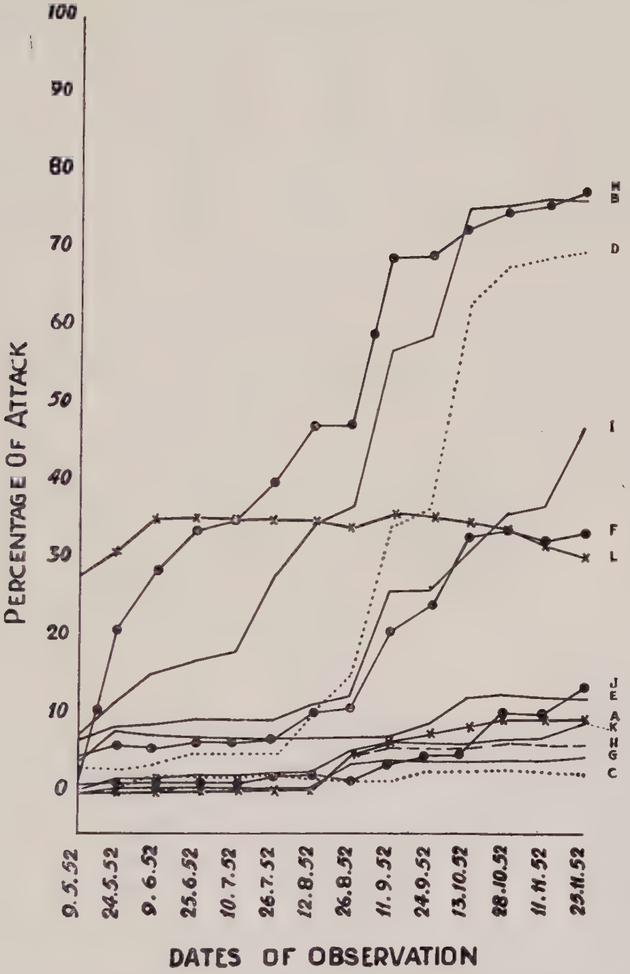
TABLE VII

EFFECT OF DIFFERENT INSECTICIDES ON TERMITES (MICRO-PLOT EXPERIMENT): 1951-52

Criteria	Setts soaked in 0.5% phenyl solution for 24 hours before planting	Setts soaked for 24 hours in a mixture of 2 oz. lead arsenate, 20 oz. lime and 30 lbs. water	Setts sprayed in furrows with parathion liquid @ 5 lbs./acre	Application of 5% BHC @ 20 lbs./acre	Application of 5% BHC @ 150 lbs./acre	Setts watered in furrows with 0.5% BHC solution @ 150 gallons/acre	Setts dusted in furrows with copper sulphate @ 40 lbs./acre	Application of 5@ DDT @ 300 lbs./acre mixed with manure	Application of 5% chlorinated camphene @ 300 lbs./acre mixed with manure	Setts dipped for 15 minutes in a mixture of 1 lb. lead arsenate and 2 gallons water having 0.1% gelatine	Setts dipped for 15 minutes in 0.25% mercuric chloride solution	Narsingham's solution 0.5% @ 100 gallons/acre	Control
Germination %*	25.33	23.33	38.00	38.33	28.33	34.33	17.33	27.33	37.00	26.33	24.66		12.00
Incidence % on :													
23-6-51*	25.55	17.10	24.90	18.52	7.99	10.79	47.24	25.47	19.43	44.20	29.08	The germination was ver poor (16.05%)	26.13
9-7-51*	44.70	26.41	30.38	24.19	9.19	12.83	53.68	31.50	25.75	57.54	37.73		29.32
24-7-51*	46.55	25.55	35.84	25.92	3.27	17.29	56.40	30.92	25.64	57.92	41.04		39.49
11-8-51*	56.28	33.85	44.78	36.45	22.35	32.75	67.59	52.08	35.09	68.98	56.61		53.87
25-8-51	59.65	47.55	61.03	42.65	24.44	46.68	71.44	50.23	42.44	75.56	71.27		49.72
12-9-51	75.06	69.47	61.38	58.46	41.24	68.40	65.79	67.48	50.29	85.12	81.75		52.62
25-9-51	77.56	66.22	66.60	62.58	48.89	72.51	90.00	74.14	62.88	85.12	81.75		80.86
15-10-51	81.31	71.07	71.07	68.45	57.69	80.27	90.00	77.35	69.28	90.00	90.00		80.86
31-10-51	90.00	73.08	76.53	65.31	65.72	81.36	90.00	78.99	77.32	90.00	90.00		82.35
17-11-51	90.00	73.08	77.73	69.22	68.96	81.36	90.00	78.99	75.37	90.00	90.00		83.21
At harvest	100.00	88.89	99.33	91.65	95.01	98.41	100.00	96.40	100.00	100.00	100.00		100.00
Yield/acre (tons)	0	9.78	3.41	6.42	1.94	0.72	0	3.19	1.92	0	0		0.66

All percentage figures transformed to $\text{Sin}^{-1}\sqrt{P}$.
*Significant at 5% level.

PLATE VI



A—Soaked overnight in 2.25 % aldrin solution.
B—Soaked 24 hours in mixture of 3 lbs. lead-arsenate, 30 lbs. lime and 46 gallons water/acre.
C—1 % aldrin solution @ 107.5 gallons/acre.
D—5 % BHC dust @ 20 lbs./acre.
E—5 % BHC dust @ 150 lbs./acre.
F—0.5 % BHC suspension @ 150 gallons/acre.
G—Soaked overnight in 1.5 % dieldrin solution.
H—0.5 % dieldrin solution @ 107.5 gallons/acre.
I—5 % Chlorinated camphene @ 300 lbs./acre.
J—Soaked overnight in 2.5 % endrin (19.5 % E.C.).
K—2.5 % endrin (19.5 % E.C.) @ 107.5 gallons/acre.
L—1 % Narsingham's solution @ 107.5 gallons/acre.
M—Control (untreated).

chlorinated camphene, DDT, aldrin and dieldrin were used. The results published by Agarwala et al (4 & 5), showed that aldrin and dieldrin provided an exceptionally good protection to the crop throughout the year and the yield recorded in such plots were the highest, being more than 4.48 tons and 4.26 tons per acre respectively over control. In the other field experiment only different formulations of BHC viz., 6.00, 2.50, 1.25 and 0.75 lbs. BHC per acre were tried to compare their efficacy. The results obtained (Table VIII) revealed that none of the treatments give any protection to the crop for more than three and a half months.

TABLE VIII

EFFECT OF DIFFERENT FORMULATIONS OF BHC ON TERMITES : 1952-53

Criteria	6 lbs. BHC/ acre applied as 0.5% sol. for dipping the setts	2.5 lbs. BHC/ acre dusted over the setts as 5% BHC @ 50 lbs. acre.	1.25 lbs. BHC/ acre dusted over the setts as 5% BHC @ 25 lbs./acre.	0.75 lbs. BHC/ acre dusted over the setts as 5% BHC @ 15 lbs./acre.	Control
Germination %*	42.23	39.48	41.50	41.43	33.90
Incidence in setts*	39.60	21.00	21.30	41.70	43.00
Tillers present in July	945	1018	925	1029	814
Incidence %age at harvest*	38.20	54.20	49.10	34.40	27.20
No. of millable canes at harvest	2449	2336	2201	2476	2229
Yield/acre (tons)	5.33	6.12	5.10	6.10	4.79
Sucrose percentage	16.58	16.81	17.38	17.75	16.79

*Significant at 5% level.

All percentage figures transformed to $Sin^{-1}\sqrt{p}$.

Field Experiment (1953-54) :—The above mentioned experiment was repeated during 1953-54. The results (Table IX) clearly bring out the fact that BHC was practically ineffective in controlling termites, so much so that the crop was prematurely harvested in October when yield varied from 0.06 tons per acre in control plots to a maximum of 0.16 tons per acre in the plots treated with 50 lbs. BHC 5% per acre. The only significant advantage noticed was during the early period of crop till the completion of germination.

TABLE IX

EFFECT OF DIFFERENT FORMULATIONS OF BHC ON TERMITES : 1953-54

Criteria	6.0 lbs. BHC/acre applied as 0.5% sol. for dipping the setts	2.50 lbs. BHC/acre dusted over the setts as 50 lbs. of 5% BHC/ acre	1.25 lbs. BHC/acre dusted over the setts as 25 lbs. of 5% BHC/acre	0.75 lbs. BHC/acre dusted over the setts as 15 lbs. of 5% BHC/acre	Control
Germination %*	31.73	32.67	31.00	31.70	22.10
Sett incidence %*	72.48	52.21	52.53	61.46	84.65
No. of shoots/acre by mid June	10,758	13,098	12,030	11,226	5,256
Incidence % Premonsoon	53.77	29.01	34.59	41.29	53.14
-do- Monsoon	68.88	65.75	72.00	70.89	67.17
-do- Postmonsoon	54.63	58.35	55.80	64.43	68.61
Yield/acre (tons)	0.11	0.16	0.09	0.08	0.06
No. of millable canes/acre by October	258	414	210	234	150

*Significant at 5% level.
All percentage figures transformed to Sin$^{-1}\sqrt{p}$.

TABLE X

EFFECT OF BHC, ALDRIN AND DIELDRIN ON TERMITES ATTACKING STANDING CROP OF SUGARCANE : 1953-54

Criteria	Application of 108 lbs. of 5% BHC/acre	Irrigation with 0.5 % BHC suspension @ 150 gallons/acre	Irrigated with 6 lbs. of dieldrin emulsion (Dieldrex 18)/acre	Irrigated with 14.4 lbs. of aldrin 40% emulsion/acre	Irrigated with chlorinatedcamphenesuspension @ 15 lbs. Toxaphene 25 % wettable powder/acre	Control (irrigated with water only)
Pre-treatment :						
Incidence %	21.01	26.31	27.08	28.41	28.28	28.69
Post-treatment :						
Incidence % monsoon*	22.80	17.45	6.85	6.06	34.14	43.44
-do- Postmonsoon*	39.48	42.27	7.10	5.54	54.29	59.82
-do- Harvest*	30.36	32.83	7.13	5.16	46.43	51.01
-do- Overall*	41.98	41.73	9.13	6.03	53.88	57.55
Yield/acre (tons)*	3.44	3.66	6.88	6.44	1.76	0.88

*Significant at 5% level.
All percentage figures transformed to Sin$^{-1}\sqrt{p}$.

Treatment of standing crop :—Agarwala *et al* (3) conducted a field experiment on the standing crop planted during 1953 Spring, which was severely infested by termites. 5% BHC dust, 50% BHC wettable powder, aldrin emulsion (40 % aldrin E.C.) dieldrin emulsion (Dieldrex 18) and chlorinated camphene (Toxaphene 25% wettable powder) were tried. They concluded from the results (Table X) that application of aldrin @ 3.3 lbs. actual per acre or dieldrin @ 1.2 lbs. actual per acre checked completely any further injury from termites attack and recorded extra yields of 5.56 tons and 6.00 tons per acre respectively over control.

They further observed that yields under BHC treatments were of the order of half those obtaind with aldrin or dieldrin.

Micro-plot Experiment (1953-54) :—In the micro plot experiment the various insecticides included were : mixture of lead arsenate and lime, aldrin, BHC, endrin and dieldrin with two different dosages of each of the last four insecticides. The results obtained (Table XI) distinctly showed that aldrin, dieldrin and endrin are very effective in checking termites (Plate VII). The lowest yield (3.32 tons per acre) was recorded from control plots, next lowest (4.94 tons per acre) being from plots where the setts were treated in furrows with BHC @ 2.5 lbs. actual per acre. The highest yield (24.54 tons per acre) was recovered from the plots where the setts were treated with dieldrin @ 1.85 lbs. actual per acre.

Aldrin and Dieldrin

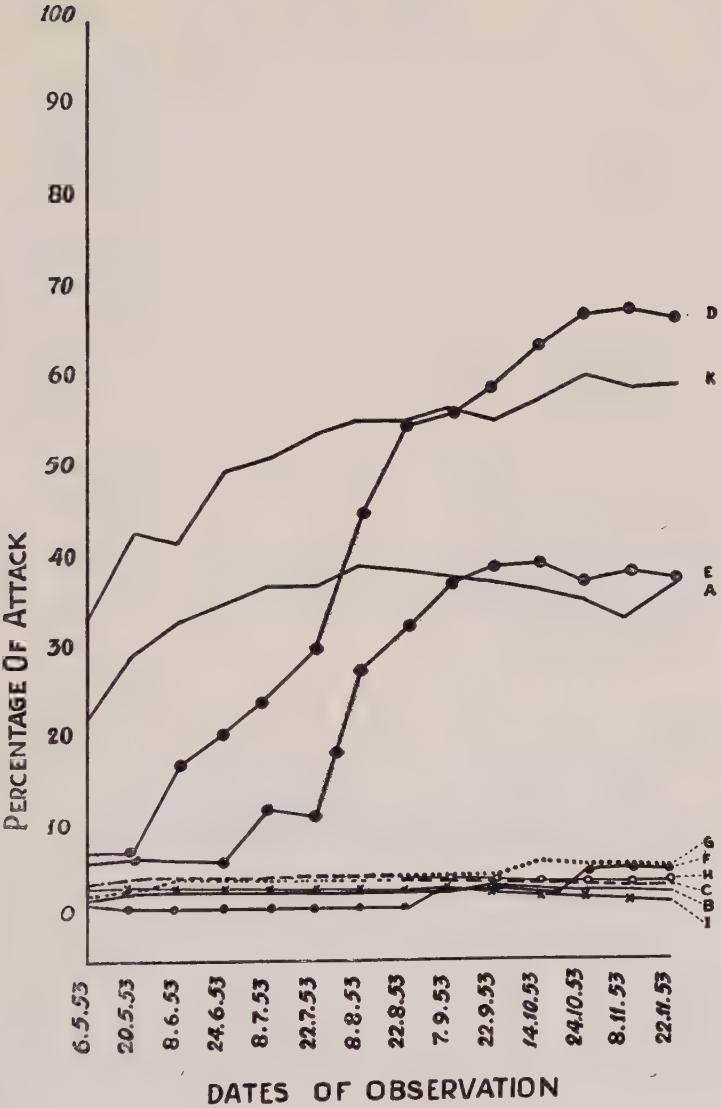
In view of the outstanding results with aldrin and dieldrin which gave complete protection to the sugarcane crop throughout the year, further trials were conducted with these two insecticides to determine the exact dose, formulation and best time of application of these insecticides. In 1954-55, one micro plot experiment and three field experiments were conducted on these lines.

Micro-plot Experiment :—The micro plot experiment was conducted to determine the best dose and formulation of aldrin and dieldrin. The results obtained showed that the dose differences were highly significant with respect to overall incidence and yield (Plate VIII). Treating the setts with 1.5 lbs. of actual aldrin or dieldrin per acre (dust or emulsion) gave the best performance against termites, while 1.0 lb. actual aldrin or dieldrin per acre gave maximum yield although there were no significant differences among the treatments.

Field Experiments :—Three experiments were conducted with the two insecticides, aldrin and dieldrin, to find out : (i) the best dose and formulation (ii) the best method of application and (iii) the best time of application.

(i) *The dose and formulation* :—Three different doses i.e., 0·5 lb., 1.0 lb. and 1.5 lbs. of actual insecticide per acre in the form of dust as well as emulsion were tried. The results obtained showed that although there was no significant difference between the behaviour of the two insecticides or their formulations (dust and emulsion), the differences due to doses were highly significant as compared to control. There were, however, no significant differences among the doses themselves.

PLATE VII



A—Soaked for 24 hours in a mixture of 3 lbs. lead-arsenate, 30 lbs. lime and 46 gallons water/acre.
B—Aldrin @ 1.25 lbs. actual/acre.
C—Aldrin @ 2.5 lbs. actual/acre.
D—5 % BHC dust @ 50 lbs./acre.
E—5 % BHC dust @ 150 lbs./acre.
F—Endrin emulsion @ 3.25 lbs. actual/acre.
G—Endrin emulsion @ 1.62 lbs. actual/acre.
H—Dieldrin @ 0.925 lbs. actual/acre.
I—Dieldrin @ 1.85 lbs. actual/acre.
J—Control (untreated).

TABLE XI

EFFECT OF DIFFERENT INSECTICIDES ON TERMITES (MICRO-PLOT EXPERIMENT) : 1953-54

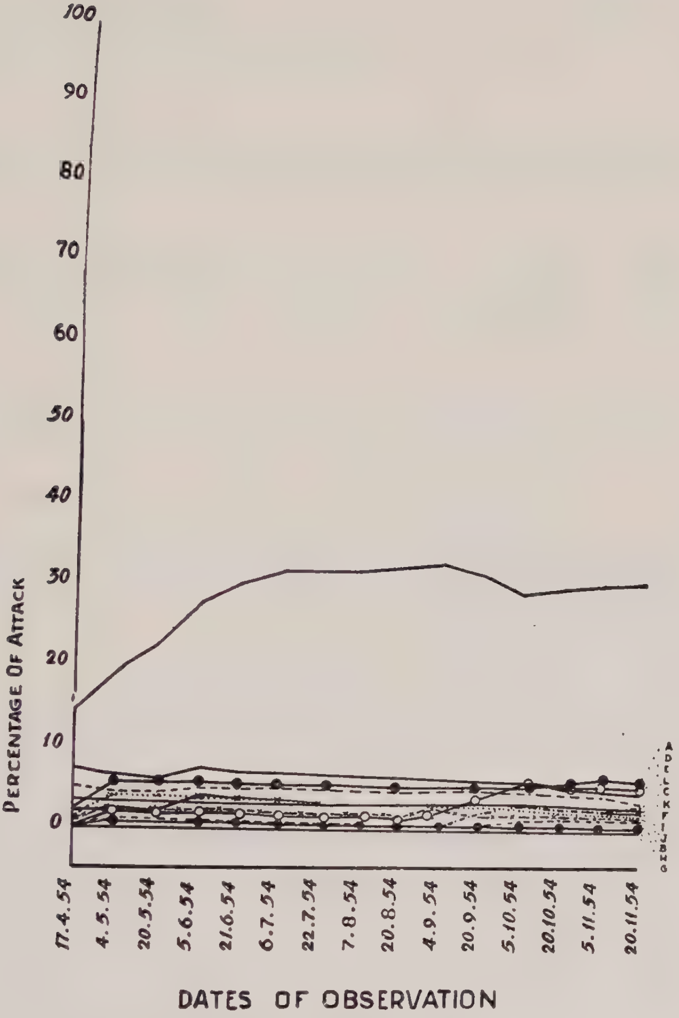
Criteria	Setts soaked for 24 hrs. in a mixture of 3 lbs. lead -arsenate, 30 lbs. lime and 460 lbs. water/acre	Setts treated in furrows with 0.5% aldrin@ 107.5 gallons/acre	Setts treated in furrows with 1.0% aldrin @ 107.5 gallons/acre	Setts treated in furrows with 5% BHC @50 lbs./ acre	Setts treated in furrows with 5%BHC@150 lbs./ acre	Setts treated in furrows with 5% endrin 19.5% E.C. @107.5 gallons/ acre	Setts treated in furrows with 2.5% endrin 19.5% E.C. @107.5 gallons/ acre	Setts treated In furrows with 0.5% dieldrln @ 107.5 gallons/acre	Setts treated in furrows with 1.0% dieldrin @ 107.5 gallons/acre	Control
Germination %	45.68	40.86	32.49	37.32	36.87	41.14	53.96	42.24	51.69	32.86
Incidence % pre-monsoon**	40.57	12.51	15.49	23.55	15.89	11.14	14.20	14.36	13.02	32.43
-do- monsoon*	21.09	9.03	9.42	40.80	34.37	9.98	7.24	7.94	7.31	32.33
-do-post-monsoon	12.41	10.63	9.50	30.07	21.35	11.93	17.61	7.68	7.06	36.73
-do- overall	43.44	13.99	13.45	50.78	59.00	14.19	19.38	12.53	11.61	61.41
Sucrose %	13.00	13.20	12.74	11.97	12.81	12.26	14.61	12.48	14.04	14.15
No. of millable canes at harvest per acre	19,960	21,780	16,638	6,655	13,008	22,083	22,385	26,018	32,368	5,143
Yield/acre (tons)	13 68	18.46	13.15	4.94	12.42	16.80	18.16	19.18	24.54	3,32

All percentage figures transformed to Sin^{-11}/p.

*Significant at 5% level.

**Significant at 1% level.

PLATE VIII



A—Aldrin emulsion @ 0.5 lb./acre.
B—Aldrin emulsion @ 1.0 lb./acre.
C—Aldrin emulsion @ 1.5 lb./acre.
D—Aldrin dust @ 0.5 lb./acre.
E—Aldrin dust @ 1.0 lb./acre.
F—Aldrin dust @ 1.5 lbs./acre.
G—Dieldrin emulsion @ 0.5 lb./acre.
H—Dieldrin emulsion @ 1.0 lb./acre.
I—Dieldrin emulsion @ 1.5 lbs./acre.
J—Dieldrin dust @ .05 lb./acre.
K—Dieldrin dust @ 1.0 lb./acre.
L—Dieldrin dust @ 1.5 lbs./acre.
M—Control (untreated).

TABLE XII

EFFECT OF DIFFERENT METHODS OF APPLICATION ON TERMITES : 1954-1955

Criteria	Insecticides	1.5 lbs. (actual) dust/acre mixed in top 6" of soil before planting	1.5 lbs. (actual) dust/acre applied as fertilizer at the time of planting	0.75 lb. (actual) dust/acre applied as M_1 and 0.75 lb. (actual) dust/acre applied as M_2	0.75 lb. (actual) dust/acre applied as M_1 and 0.75 lb. (actual) dust/acre dusted over the setts in furrows	1.5 lbs. (actual) dust/acre dusted over the setts in furrows	Setts soaked for 1/2 hour in emulsion @ 1.5 lbs. (actual) insecticides/acre	1.5 lbs. (actual) dust/acre rubbed over the setts before planting	Control (untreated)
		M_1	M_2	M_3	M_4	M_5	M_6	M_7	M_8
Germination % **	Aldrin	37.06	34.88	37.45	36.19	35.29	34.24	33.30	28.64
	Dieldrin	36.12	36.01	37.45	38.03	37.62	38.08	38.95	25.92
Sett Incidence %**	Aldrin	35.50	11.87	12.92	12.03	12.66	21.03	12.51	85.34
	Dieldrin	52.02	17.08	18.86	16.58	12.11	15.63	13.15	90.00
Incidence % during :									
April II fortnight**	Aldrin	7.30	7.23	7.80	7.21	6.91	6.88	8.72	14.09
	Dieldrin	10.31	6.53	7.09	5.99	6.64	6.68	6.56	27.84
May I fortnight**	Aldrin	7.20	6.27	6.44	6.84	6.11	5.86	6.69	12.08
	Dieldrin	5.96	5.49	7.44	5.35	6.27	5.89	5.97	10.55
May II fortnight**	Aldrin	5.22	5.79	5.30	6.64	5.81	5.58	5.76	15.32
	Dieldrin	5.73	5.49	5.31	5.51	5.36	5.71	5.41	18.92
June I fortnight**	Aldrin	6.06	5.51	5.54	5.73	5.73	5.66	6.13	19.56
	Dieldrin	6.64	5.44	5.17	5.27	5.39	5.28	5.78	18,49
June II fortnight**	Aldrin	7.88	6.33	5.77	6.05	6.02	7.91	6.63	17.36
	Dieldrin	7.80	5.26	5.98	5.63	5.70	5.83	5.54	19.06
July I fortnight**	Aldrin	5.93	5.25	5.33	6.05	5.69	7.43	5.60	16.71
	Dieldrin	5.10	5.09	5.57	4.64	5.21	6.48	5.74	18.24

July II fortnight**	Aldrin	8.61	9.15	5.70	6.78	6.18	1.87	8.40	20.89
	Dieldrin	7.56	5.31	5.59	5.57	5.58	17.47	5.91	18.88
August I fortnight**	Aldrin	67.04	6.19	5.77	6.80	6.06	11.97	7.99	23.15
	Dieldrin	6.20	5.76	6.14	5.65	6.04	13.49	7.56	21.67
August II fortnight**	Aldrin	7.24	6.41	7.16	6.19	8.30	16.84	5.82	17.97
	Dieldrin	1.05	6.25	6.06	6.78	7.04	11.49	6.70	21.46
Sept. I fortnight**	Aldrin	0.16	7.65	5.74	8.24	7.14	16.01	9.42	21.87
	Dieldrin	9.90	7.37	6.76	8.86	13.01	20.68	10.57	26.08
Sept. II fortnight**	Aldrin	8.21	7.05	5.84	7.99	7.47	16.55	8.41	23.69
	Dieldrin	7.33	9.00	5.76	5.89	7.56	20.76	5.85	24.11
October I fortnight**	Aldrin	7.47	8.15	6.08	6.99	6.13	18.69	10.81	28.61
	Dieldrin	7.63	5.64	6.93	6.86	6.62	19.70	7.09	26.63
October II fortnight**	Aldrin	9.49	7.25	7.22	7.81	5.98	12.50	9.20	31.46
	Dieldrin	8.48	9.41	5.75	5.84	5.72	17.59	8.10	25.93
Nov. I fortnight**	Aldrin	9.44	9.87	7.08	6.36	7.62	9.76	6.73	26.05
	Dieldrin	10.66	9.86	5.90	6.67	7.05	15.12	8.92	23.59
Nov. II fortnight**	Aldrin	10.19	8.73	8.20	6.62	7.01	15.94	9.26	22.34
	Dieldrin	9.96	7.56	6.01	5.65	7.32	15.02	8.64	25.93
Dec. I fortnight**	Aldrin	25.72	17.77	14.86	16.53	19.76	31.90	20.69	40.67
	Dieldrin	19.28	15.40	12.43	13.61	13.28	30.35	21.09	48.28
No. of millable canes/acre at harvest**	Aldrin	27815	26245	27325	28525	28767	27110	28465	17240
	Dieldrin	26675	29808	29615	30170	27960	25010	29620	15060
Yield/arce (tons)*	Aldrin	12.39	15.07	17.10	16.51	16.95	13.60	16.47	8.09
	Dieldrin	14.04	16.91	15.59	15.77	15.51	12.28	15.48	6.03

All percentage figures transformed to Sin $^{-1}\sqrt{p}$.

*Significant at 5% level.

**Significant at 1% level.

(ii) *The method of application* :—A fixed dose of 1.5 lbs. of actual insecticide per acre was applied by seven different methods. The results obtained (Table XII) showed that the application of insecticides in furrows whether mixed with soil or used over the setts was definitely superior. The method of application differences were not only significant as compared to control, but also among themselves.

(iii) *The time of application* :—In this experiment 1.0 lb. actual aldrin or dieldrin per acre was applied at three different times i.e. at the time of planting or two months after planting or three months after planting. The results (Table XIII) revealed that the application of either of the insecticides at the time of planting was significantly better than the post-planting application. Thus the findings indicate the desirability of adopting insecticidal treatments within the regular cultural schedule of sugarcane cultivation on termite infested lands.

TABLE XIII

EFFECT OF DIFFERENT TIME OF APPLICATION OF ALDRIN AND DIELDRIN ON TERMITES : 1954-55

Criteria	Aldrin @ 1.0 lb. actual applied			Dieldrin @ 1.0 lb. actual applied			Control
	at the time of planting	2 months after planting	3 months after planting	at the time of planting	2 months after planting	3 months after planting	
Germination percentage*	32.37	25.87	24.01	25.72	23.97	24.19	24.32
Incidence %*	18.98	85.57	79.57	15.04	85.57	75.95	82.89
Millable canes at harvest/acre*	25500	19555	15645	28050	19855	16990	12950
Yield/acre (tons)*	15.08	11.69	9.15	13.76	12.30	11.04	6.23

*Significant at 5% level.
All figures except of yield, transformed to $\text{Sin}^{-1}\sqrt{p}$.

CONCLUSION

Application of various chemicals to the setts at the time of planting has been found useful in warding off attack of the pest. The duration of effectiveness varies from chemical to chemical. There is, however, no evidence that any of the chemicals kill the pest and make the fields permanently free. It has been observed that due to the offensive odours and general distastefulness imparted to the setts by the various chemicals, the termites migrate to the lower layers of the soil and remain there as long as the noxiousness and effective repellance of that individual chemical lasts ; thereafter, the termites once again come up and attack the crop. This necessitates the use of a chemical that would be able to repel the pest from the time of planting the crop till harvest.

From the results of experiments conducted in this connection it is clear that aldrin, dieldrin and endrin are the only insecticides that give protection to the crop all through its life. These insecticides must therefore be regarded as the most effective treatments against termites in sugarcane fields. Endrin, however, is very expensive and therefore aldrin or dieldrin is preferable from economic consideration. Applied as dust or emulsion @ 0.5-1.0 lb. actual insecticide per acre at the time of planting both aldrin and dieldrin prove outstanding. Dieldrin being less volatile than aldrin, its effects last longer but it is somewhat more expensive than aldrin. It is therefore suggested that aldrin, dust or emulsion @ 1 lb. of actual chemical per acre be included in the regular cultural schedule for sugarcane planting in termite infested fields. The cost of the chemical amounts to Rs. 11/- to Rs. 12/- per acre, the cost of application being Rs. 1/- per acre.

SUMMARY

Termites, a major pest of sugarcane, are widely distributed all over the world. A complete list of species recorded so far has been includedi n the paper. Attempts to control the pest are being made in India for the last 40 years or more. In exhaustive studies undertaken in the State of Bihar, the efficacy of various indigenous control measures was examined in detail, but these proved to be of little avail. Various chemicals (repellants and deterrents) were also examined. Amongst the earlier chemicals, none gave protection against termites for more than a month, and as such had to be discarded. Among newer insecticides examined, BHC afforded protection for about 5 months, but in heavy doses it proved harmful to the crop. Aldrin, dieldrin and endrin gave protection to the crop right upto its harvest. Of these endrin was very expensive and therefore the application of aldrin and dieldrin alone were recommended as dust or emulsion, either mixed in the soil or spread over the planted setts in the furrows, the dosage being 1.0 lb. (actual) per acre. As between aldrin and dieldrin, the former is somewhat cheaper (Rs. 12/- per acre including cost of application) and is therefore preferred.

ACKNOWLEDGMENTS

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Paper

ON TILLER MORTALITY AND COMPENSATION DUE TO BORERS IN SUGARCANE

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INTRODUCTION

Borers in sugarcane cause a heavy loss right from almost germination of the crop till its harvest. In the earlier stages when mother shoots alone are available, the mortality is severe with the result that patchy stands are not uncommon (Khanna, 1946). Later, however, when the crop enters its tillering phase, 'dead-heart' production need not lead to mortality of the complete plant, for daughter shoots continually emerge and compensate the loss occasioned by borers in a varying degree depending upon variety under cultivation, conditions of growth and time of the year (Khanna, 1948). It is of importance, therefore, to determine precisely mortality and compensation indices besides loss in weight and sugar due to the incidence of borers at different stages of crop growth and for this purpose it is necessary to record observations relating to both the host plant and the pest throughout the life cycle of the crop. Thus observations on the (i) rapidity and intensity of germination, (ii) periodical emergence of tillers, (iii) their mortality and the causal agent responsible, (iv) dead-heart production and reasons therefor, (v) growth history in terms of stalk length and number of joints and in relation to borer incidence and the length and joints affected thereby for each of the three borers viz., top, stem and root severally and jointly and (vi) finally loss in weight and quality based on performance of healthy and affected stalks, have to be taken meticulously and on the basis of sound sampling procedure to ensure valid results (Khanna 1951).

The problem of estimating compensation presents practical difficulties as dead-hearts continue to occur concurrently with the emergence of tillers during the growth cycle with the result that it is not possible to isolate the tillers that come out as a consequence of dead-heart occurrence or to determine the stage at which incentive to increased production begins. Comparison, however, of number of tillers that emerge upto harvest in a clump with the total number of dead-heart occurrences in the same can throw considerable light on the problems ; for if a high positive correlation between total dead-heart occurrence and total emergence (clumpwise) exists, it may be safely concluded that increased deadheart occurrences have brought about production of extra tillers. In view of the fact that correlation coefficient does not say anything about the causal agent, there may be an argument against the acceptance of the above postulate. As, however, all canes in a field have equal chance of being attacked by borers and as a clump with larger number of tillers provides more points of attack, it may be contended that this correlation is due to increased dead-hearts being a consequence of increased emergence rather than being a cause. An emprical approach has, therefore, been adopted in the investigation of this problem.

In a field, there will exist side by side clumps which have remained healthy all through i.e. free from borer infestation and clumps which have shown dead-hearts at one time or the other during the season. If the number of healthy clumps in a field is quite large, the normal rate of tillering can be evaluated and compared with the corresponding rate of emergence of affected clumps subsequent to dead-heart occurrence. The difference between these two rates will obviously indicate as to whether there is compensatory tillering or not.

MATERIALS AND METHODS

The experiments were conducted at Pusa over a period of ten years with three varieties (Co. 313, Co. 356 and Co. 421) under randomised blocks in eight replications. The border rows were eliminated, observations being recorded only in the ultimate plots of 1/40th acre, each consisting of five rows 75 feet long. The sampling procedure adopted for recording various observations was as follows :

(1) *Mortality index and compensation index* : In each plot four random eleven-feet units were selected—one from each of four succeeding rows, leaving the fifth row for recording yield at harvest. After one month of planting, weekly germination counts were taken and recorded. Each clump within the selected units was numbered serially and each tiller labelled and numbered according to its date of emergence (Plate I-a, b and c). Weekly examination of these labelled clumps was carried out and tiller emergence, formation of dead-hearts, shoot mortality

D.H.
M.P.
D.H.
D.H.
D.H.
D.H.
M.P.
2

Plate I (*a*) : Showing different stages of tagging mother and daughter shoots. M.P. represents mother shoot ; D.H., dead-heart ; numerals, the tiller number (denominator) and week of emergence (numerator).

Plate I (*b*) :Showing tagging at a later stage.

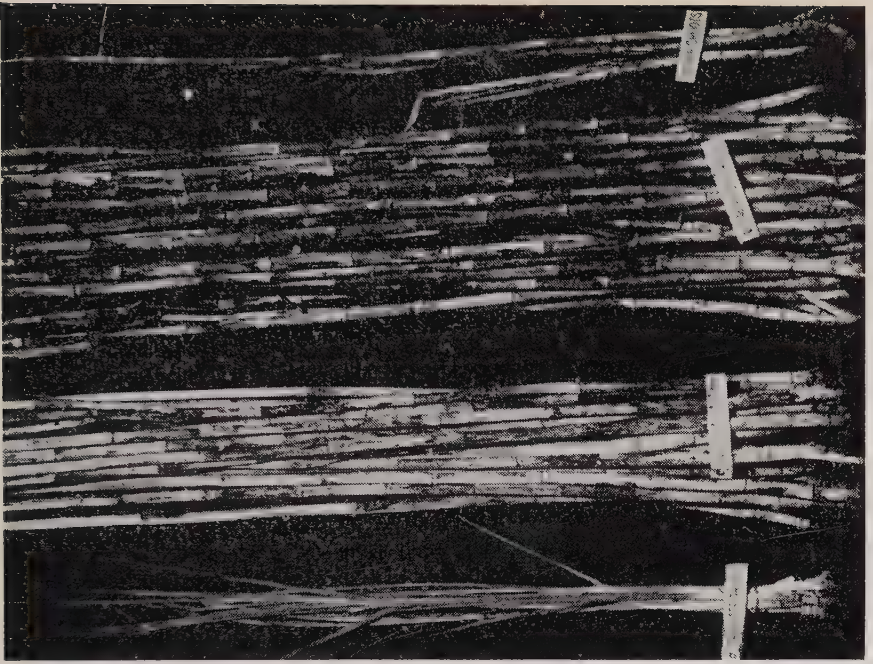


Plate I (*c*) : Showing proceeds from mother and different category daughter shoots at harvest.

as also the causal agents recorded. At the time of harvest, the observations on (i) number of canes in clump, (ii) length, weight and number of joints in each cane, (iii) length and joints affected by each of the borers or other pests or diseases were recorded after splitting open the canes longitudinally. The canes of each unit so harvested were then crushed individually and juice quality determined. The data thus obtained were recorded.

(2) *Loss in yield and sugar due to pests* : In addition to the observations mentioned above, 16 random clumps were selected from each plot ; four from each row. The canes in these clumps were stripped of their leaves and topped. The number of canes in each clump, the length and number of joints in each cane as also its weight were recorded. The canes were then split open longitudinally and the number of joints and length of canes affected by each of the borers were also recorded, along with their species and stage of the pest and disease, if any. The canes so examined, were grouped as follows : (i) healthy, (ii) top bored only, (iii) stem bored only, (iv) root bored only, (v) top and stem bored, (vi) top and root bored, (vii) stem and root bored, (viii) top, stem and root bored and (ix) affected by other pests with any of the borers above. These groups of canes were crushed separately and the juices examined for extraction, brix, sucrose percent and purity. Another sample of three clumps was selected at random and crushed for juice analysis without splitting the canes. The plot yield and number of stalks were recorded from the rows reserved for the purpose. Partial regression equations based on all these observations afforded an estimate of the loss in cane weight and deterioration in juice quality.

The data thus collected were examined to see whether dead-heart occurrence or mortality caused by sugarcane borers was followed by compensatory emergence of extra tillers and if so, to estimate the indices of compensation. In this connection, the clumps were also classified into three groups with reference to borer infestation and mortality. An attempt was likewise made to estimate the following :

1. Association if any, between tillering capacity and compensation index.
2. Variations in tillering and mortality due to season and varieties.
3. Loss in weight and juice quality due to borer infestation.
4. Influence of age of tillers on weight and juice quality.

CLASSIFICATION OF CLUMPS

The clumps available have, therefore, been classified into three different categories :

Class I : Clumps which had emergence after dead-heart occurrence or mortality due to borers,

Class II : Clumps which had no emergence subsequent to dead-heart or mortality due to borers and

Class III : Clumps which remained healthy all through i. e., free from borer infestation.

The number of clumps under each class has been expressed as percentage of the total number available for each variety. The figures for different years are shown in Table I.

TABLE I

SHOWING PERCENTAGE OF CLUMPS UNDER DIFFERENT CLASSES

Season	Co. 313 Class I	Co. 313 Class II	Co. 313 Class III	Co. 356 Class I	Co. 356 Class II	Co. 356 Class III	Co. 421 Class I	Co. 421 Class II	Co. 421 Class III
1942-43	9.5	59.5	31.0	51.6	29.0	19.4	11.6	51.2	37.2
1943-44	34.1	36.9	29.0	37.2	36.0	26.8	17.7	48.0	34.3
1944-45	36.8	42.2	21.0	27.3	22.9	49.8	28.7	30.6	40.7
1945-46	56.3	35.0	8.7	57.9	31.0	11.1	57.3	32.1	10.6
1946-47	53.7	37.4	8.9	40.9	37.1	22.0	50.6	34.2	15.2
1947-48	34.1	51.6	14.3	35.7	47.6	16.7	34.0	45.9	20.1
1948-49	29.8	34.8	35.4	37.3	19.5	43.2	33.6	16.4	50.0
1949-50	26.6	30.2	43.2	33.7	23.3	43.0	20.1	24.8	55.0
1950-51	28.6	26.5	44.9	14.7	27.8	57.5	21.3	27.2	51.5
1951-52	17.7	22.4	59.9	20.4	24.9	54.7	21.1	14.1	64.8

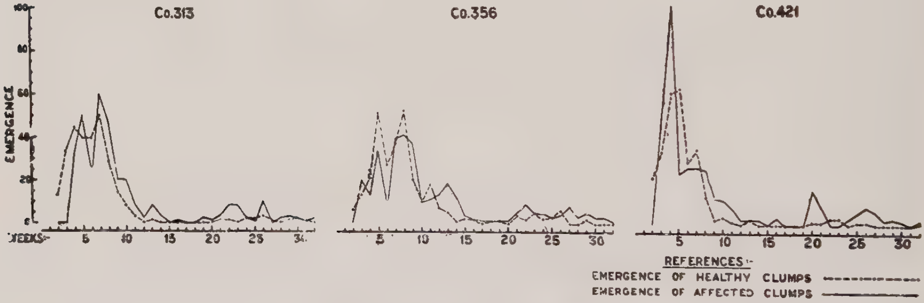
The proportion of healthy clumps varied during the ten seasons from 8.7 % to 59.9 %, 11.1 % to 57.5% and 15.2% to 64.8 % in Co. 313, Co. 356 and Co. 421 respectively. Maximum percentages were obtained during the four seasons 1948-49 to 1951-52 for all the three varieties. The proportion of healthy clumps was minimum during 1945-46 for varieties Co. 313 and Co. 356 and during 1946-47 in variety Co. 421. The proportion of clumps under Class II is in general lower and that of healthy clumps higher in Co. 356.

The clumps under both categories I and II suffered loss of shoots due to dead-hearts. But clumps under Class II did not show any emergence following dead-heart occurrence. Consequently, they did not contribute anything towards compensation. Compensation, if any, could be provided only by clumps under Class I which showed emergence subsequent to dead-heart occurrence. It is to be seen to what extent they have been able to compensate the loss of shoots sustained by both the classes.

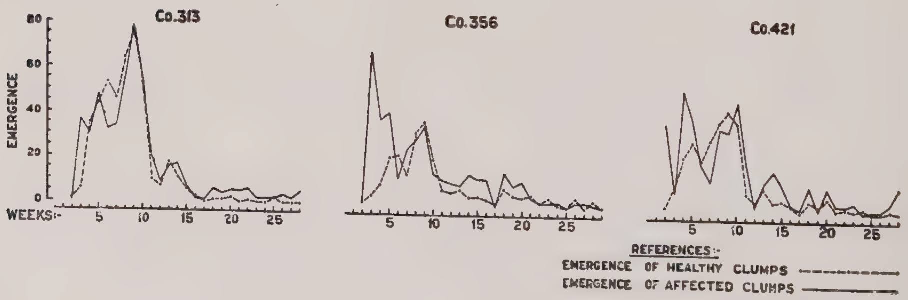
DEFINITION OF NORMAL EMERGENCE

Normal emergence may be defined as the rate of tillering of Class III clumps i.e. clumps which remained free from borer infestation all through the season. The proportions of such clumps have been too small in some seasons to warrant calculation of this normal rate. Besides this, it has been noticed that these clumps have, in general, produced less number of tillers. A clump has, therefore, been reckoned as healthy till dead-heart has been noticed in it, that is to say if a clump has shown dead-hearts in a particular week it has been taken as healthy upto that week and as affected during subsequent weeks. This definition covers the rate of tillering of a considerably large proportion of clumps comprising all the three classes. The normal rates of tillering during the different weeks in respect of the three varieties have been graphically represented in Figs. (1.1—1.9) separately for each season. The rates of emergence of affected clumps (Class I) have been superimposed on the normal rates.

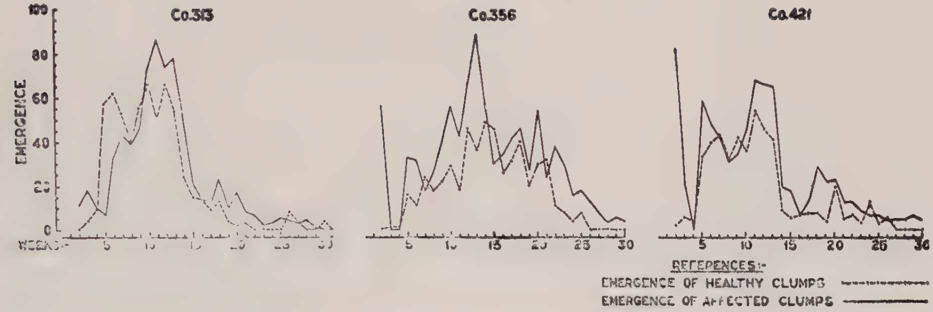
WEEKLY EMERGENCE (PER HUNDRED)
OF HEALTHY & AFFECTED CLUMPS
PUSA 1943-44



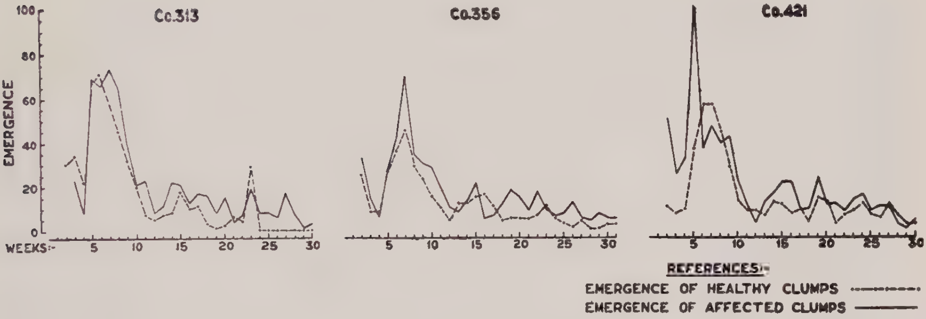
WEEKLY EMERGENCE (PER HUNDRED)
OF HEALTHY & AFFECTED CLUMPS
PUSA 1944-45



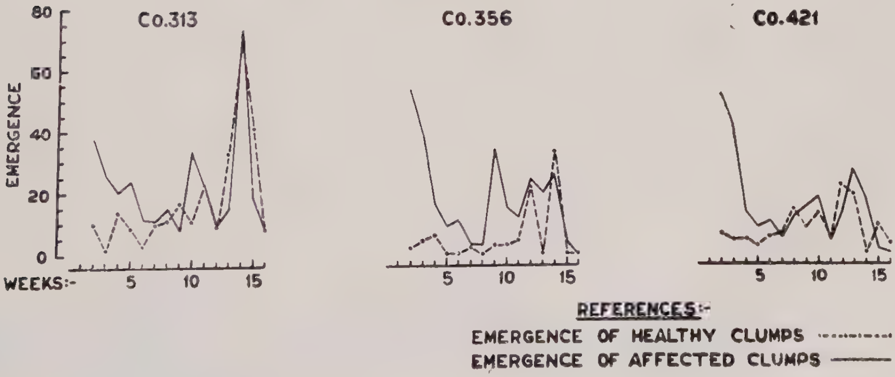
WEEKLY EMERGENCE (PER HUNDRED)
OF HEALTHY & AFFECTED CLUMPS
PUSA 1945-46



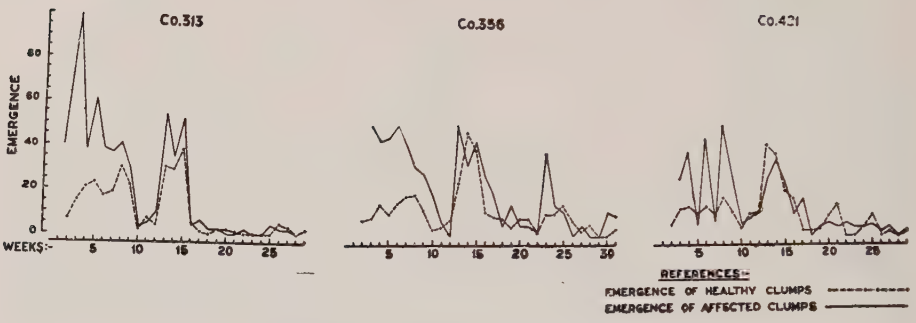
WEEKLY EMERGENCE (PER HUNDRED)
OF HEALTHY & AFFECTED CLUMPS
PUSA 1946-47



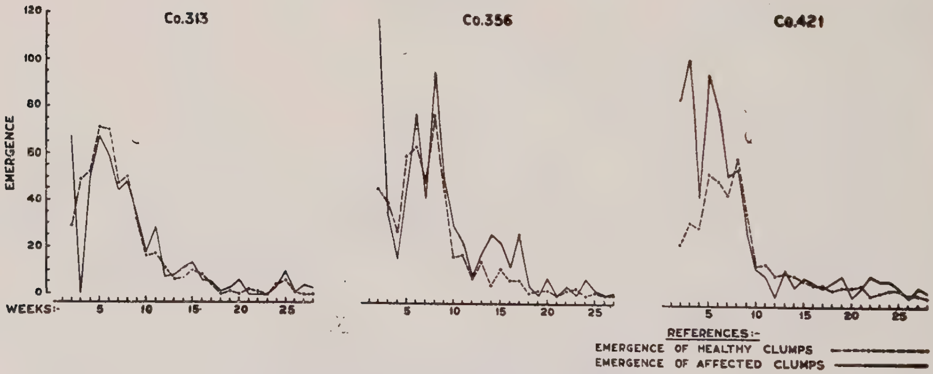
WEEKLY EMERGENCE (PER HUNDRED)
OF HEALTHY & AFFECTED CLUMPS
PUSA 1947-48



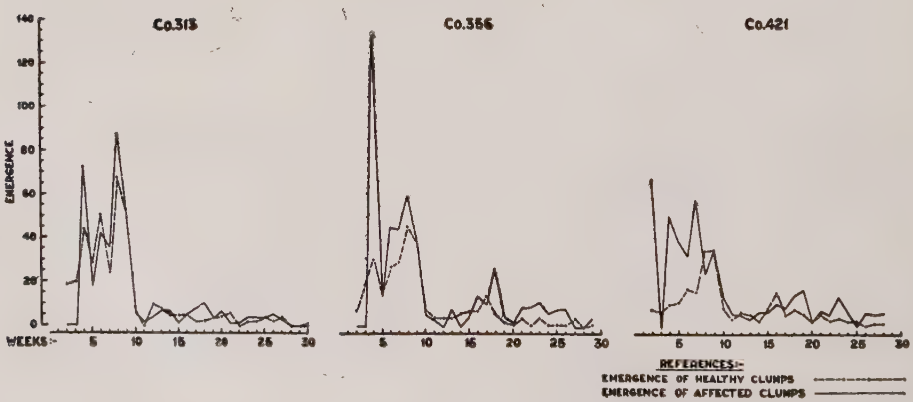
WEEKLY EMERGENCE (PER HUNDRED)
OF HEALTHY & AFFECTED CLUMPS
PUSA 1948-49

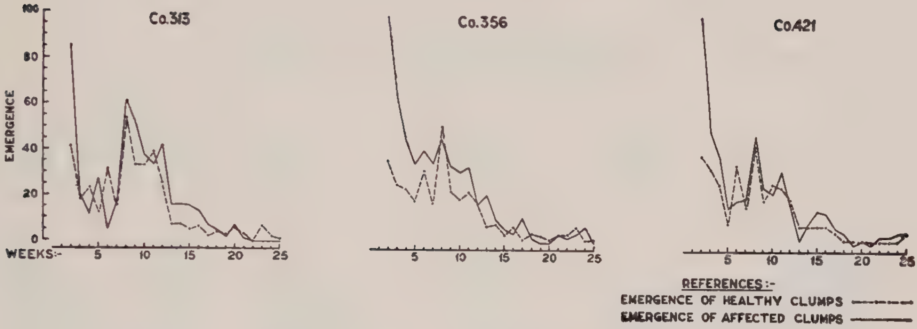


WEEKLY EMERGENCE (PER HUNDRED)
OF HEALTHY & AFFECTED CLUMPS
PUSA 1949-50



WEEKLY EMERGENCE (PER HUNDRED)
OF HEALTHY & AFFECTED CLUMPS
PUSA 1950-51





WEEKLY EMERGENCE (PER HUNDRED)
OF HEALTHY & AFFECTED CLUMPS
PUSA 1951-52

CALCULATION OF COMPENSATION

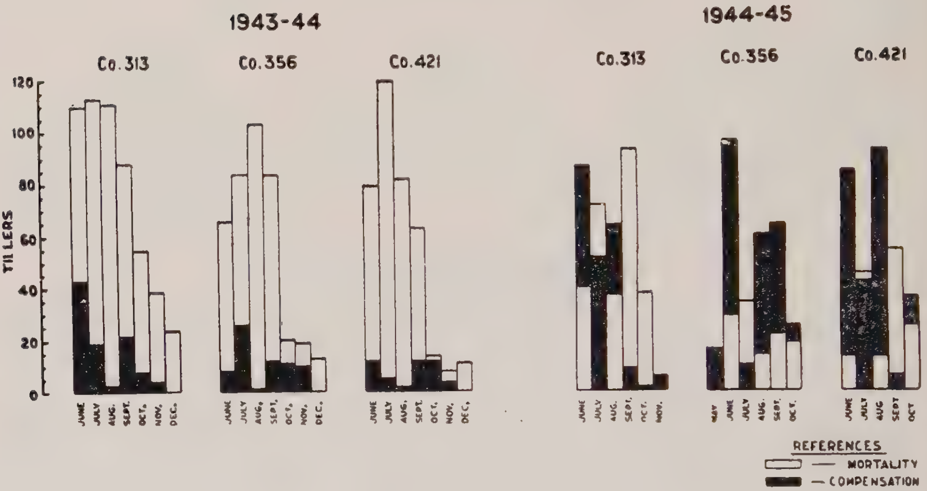
It will be noticed from these figures that the tillering potentiality of affected clumps is somewhere higher and somewhere lower than the corresponding normal rate. The above potentialities have been calculated on the basis of clumps under Class I and tillers produced by these clumps subsequent to dead-hearts or mortality due to borers. The difference between these two multiplied by the corresponding number of affected clumps showing emergence would, therefore, indicate whether there are extra tillers by way of compensation or not. If it is noticed that the normal rate in any particular week is less than the rate shown by the affected clumps (Class I), there will be compensation during that week ; while compensation will not be considered to have accrued if the normal rate happens to be higher or equal. The resultants (Table II) calculated over the entire season reveal that there has been an increased emergence of shoots in all the varieties every season.

TABLE II

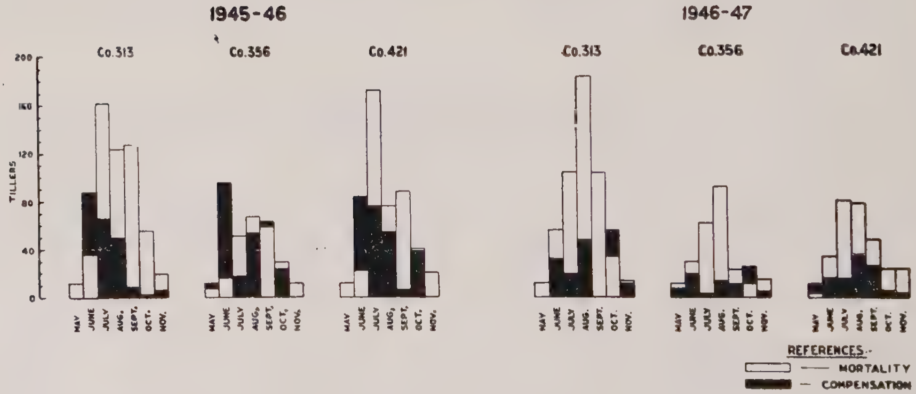
SHOWING RESULTANT EXTRA EMERGENCES AND MORTALITIES IN CLUMPS UNDER CLASS I AND CLASS II

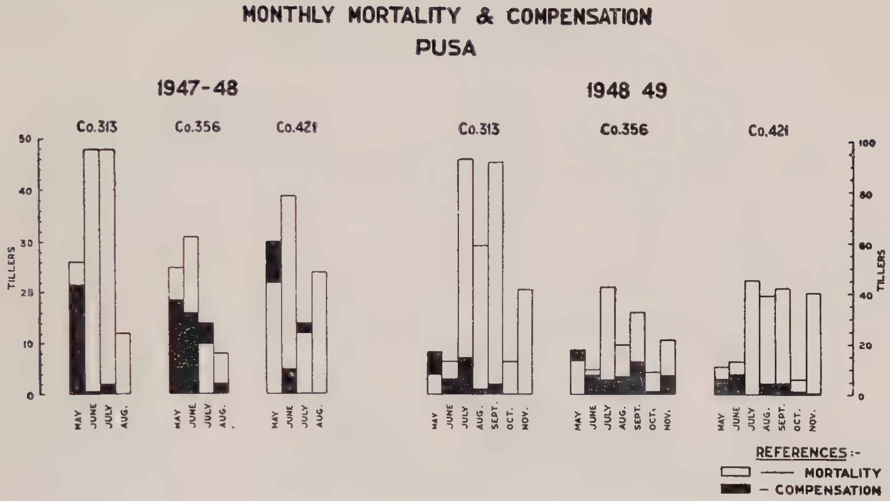
Season	Co. 313		Co. 356		Co. 421	
	Emergence	Mortality	Emergence	Mortality	Emergence	Mortality
1942-43	4	63	20	51	4	51
1943-44	88	555	89	400	46	385
1944-45	38	280	37	118	46	150
1945-46	204	536	276	215	257	407
1946-47	161	506	94	244	118	288
1947-48	11	135	51	74	42	97
1948-49	48	203	64	105	14	121
1949-50	15	175	89	194	45	118
1950-51	39	44	20	29	36	49
1951-52	24	88	60	116	34	70

MONTHLY MORTALITY & COMPENSATION
PUSA



MONTHLY MORTALITY & COMPENSATION
PUSA




MONTHLY MORTALITY & COMPENSATION
PUSA
1947-48
1948 49
Co.313
Co.356
Co.421
Co.313
Co.356
Co.421
TILLERS
0
10
20
30
40
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TILLERS
0
20
40
60
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100
MAY
JUNE
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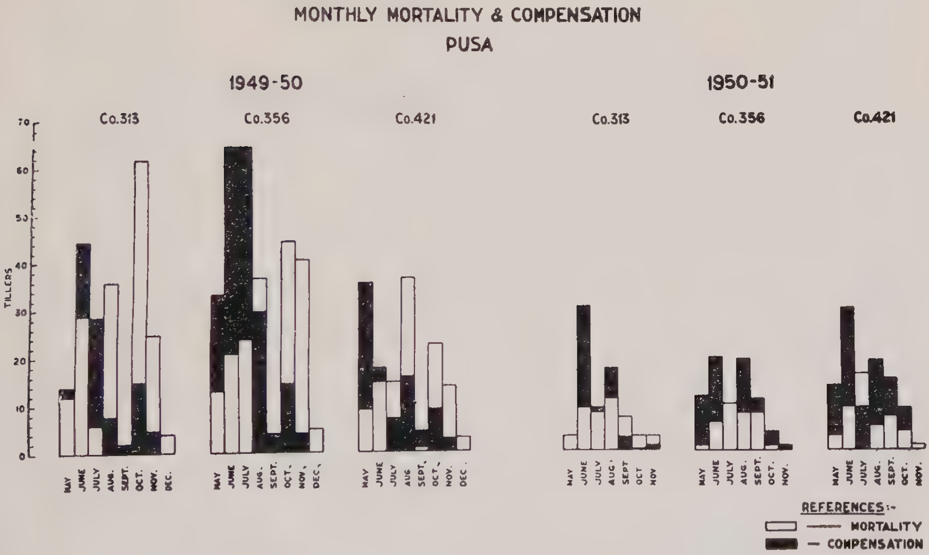
REFERENCES:-
MORTALITY
COMPENSATION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PUSA
1949-50
1950-51
Co.313
Co.356
Co.421
Co.313
Co.356
Co.421
TILLERS
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MAY
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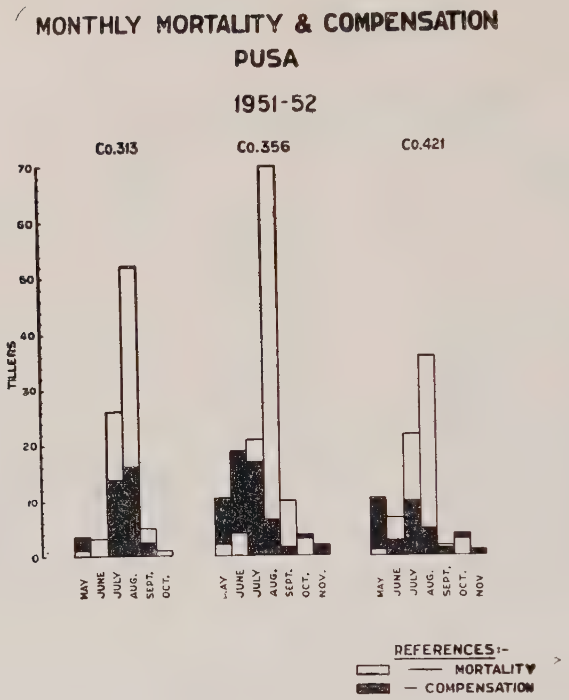
REFERENCES:-
MORTALITY
COMPENSATION


MONTHLY MORTALITY & COMPENSATION
PUSA
1951-52
Co.313
Co.356
Co.421
TILLERS
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MAY
JUNE
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REFERENCES:-
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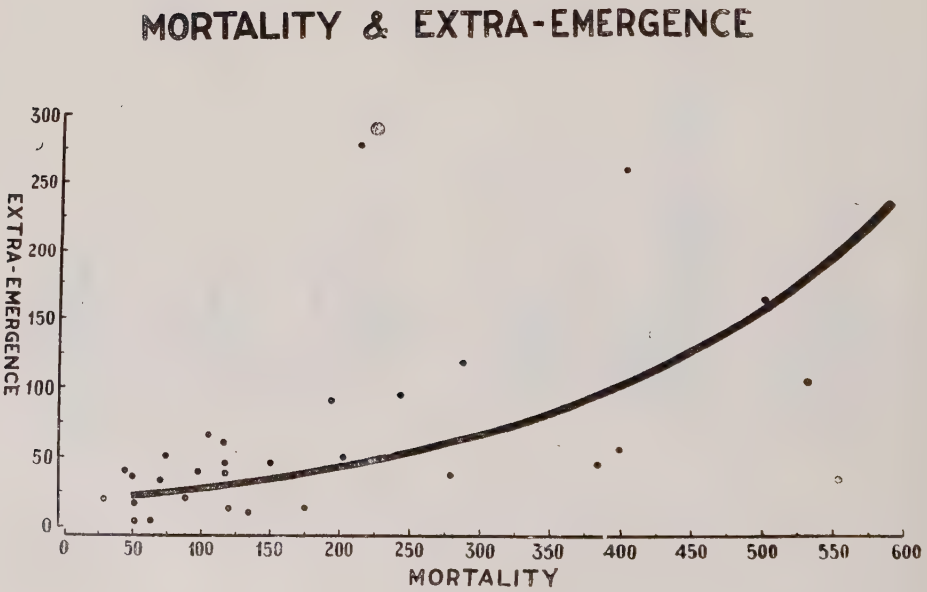
COMPENSATION


MORTALITY & EXTRA-EMERGENCE
EXTRA-EMERGENCE
0
50
100
150
200
250
300
0
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100
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250
300
350
400
450
500
550
600
MORTALITY

Information on the mortalities sustained by clumps under Class I and II is also available in the above Table. These mortalities do not include those due to causes other than borer infestation. Of the various such causes, termites have been found to take the heaviest toll of tillers.

INDEX OF COMPENSATION

The resultant extra emergences expressed as percentages of the total mortalities suffered jointly by classes I and II will provide the required indices of compensation. The orders of compensation obtained for the three varieties during the ten seasons have been shown in Table III.

TABLE III

SHOWING PERCENTAGE COMPENSATION CALCULATED ON THE BASIS OF EMERGENCES OF CLASS I, CLASS II AND CLASS III

Seasons	Co. 313	Co. 356	Co. 421
1942-43	6.54	39.26	7.98
1943-44	15.77	22.84	12.04
1944-45	13.56	31.18	30.57
1945-46	37.94	128.23	63.25
1946-47	31.77	38.33	40.83
1947-48	7.95	69.08	43.18
1948-49	23.54	61.23	11.27
1949-50	8.66	45.63	24.05
1950-51	88.97	67.56	74.25
1951-52	27.12	51.85	48.03

Leaving out of consideration the results obtained during the season 1942-43 in respect of which the tillering rates have been estimated on the basis of a very small number of clumps, it will be noticed that compensation percentages ranged between 7.95% to 88.97%, 22.84% to 128.23% and 11.27% to 74.25% in Co. 313, Co. 356 and Co. 421 respectively. Percentage compensation has been, in general, maximum in Co. 356. During 1945-46 this variety, over and above compensating completely for the loss of shoots has given about 28% more tillers. It has been already noticed that Co. 356 had in general a greater proportion of healthy clumps and smaller proportion of Class II clumps. Co. 421 occupies the intermediate position in this respect.

It will be interesting to study the changes in the orders of compensation when they are based on the rates of tillering of clumps under Class III only. Table IV furnishes these figures.

TABLE IV

SHOWING PERCENTAGE COMPENSATION CALCULATED ON THE BASIS OF EMERGENCE OF CLASS III

Season	Co. 313	Co. 356	Co. 421
1943-44	27.12	37.24	21.36
1944-45	57.59	49.15	47.35
1945-46	101.39	316.26	148.35
1946-47	56.89	47.56	47.99
1947-48	6.75	67.50	92.48
1948-49	38.88	84.30	34.90
1949-50	24.13	63.81	38.41
1950-51	143.35	149.52	110.87
1951-52	34.29	56.87	68.83

It will be noticed from the above Table that there have been marked increases in the indices of compensation and in most of the cases they have multiplied several times. Co. 356 has now recorded a value as high as 316%.

RATES OF EMERGENCE IN SUBSEQUENT WEEKS OF CLUMPS AFFECTED IN A PARTICULAR WEEK

The phenomenon of compensatory tillering has been further sought to be substantiated by splitting up the rate of tillering of affected clumps into component parts in the following manner. Suppose, in a particular week twenty-five clumps have shown dead-heart occurrences. The emergence rates of these twenty-five clumps in subsequent weeks have been evaluated and compared with the corresponding normal rate. It has been noticed that these rates are somewhere higher and somewhere lower than the normal values. However, one should be cautious in the interpretation of the above results, because the number of clumps on which these rates are based is very small.

It may be argued that the clumps under Class I which have shown extra emergence would have produced these extra tillers even in the absence of dead-heart occurrence because they possessed an intrinsic potentiality for producing more tillers. To investigate into this matter, the rates of tillering of these clumps till dead-heart occurrence have been separately calculated in the same manner as the normal rate and are shown in Tables (V.1—V.9). The figures which are higher than the corresponding rate of affected clumps have been underlined. It will be seen in these Tables that these values have exceeded the rates shown by their affected sisters for a comparatively smaller number of periods. One point may, however, be made that the number of these clumps gradually dwindles to zero.

The rates will therefore be comparable only in cases where the number of clumps is sufficiently large. The resultants calculated still show extra emergences furnishing further evidence of compensatory tillering.

TABLE V. 1.

SHOWING RATE OF EMERGENCE OF HEALTHY CLUMPS IN CLASS I
YEAR : 1943-44

Date	Co. 313		Co. 356		Co. 421	
	No. of clumps	Rate of emergence	No. of clumps	Rate of emergence	No. of clumps	Rate of emergence
22-4-43	121	0.2562	118	0.0932	62	0.4242
6-5-43	119	0.4958	112	0.1786	60	0.4343
13-5-43	110	0.6363	105	0.4095	51	0.6863
20-5-43	99	0.8081	98	0.5306	45	0.5778
27-5-43	82	0.5366	85	0.5059	40	0.4500
3-6-43	50	0.3800	72	0.4444	31	0.4838
10-6-43	37	0.3243	55	0.7273	23	0.4347
17-6-43	29	0.3448	32	0.2500	18	0.1667
24-6-43	20	0.1500	20	0.0000	15	0.0000
1-7-43	15	0.0000	13	0.1538	12	0.0000
10-7-43	14	0.0000	11	0.0909	10	0.0000
15-7-43	11	0.0909	9	0.2222	10	0.1000
22-7-43	9	0.0000	9	0.1111	7	0.0000
29-7-43	5	0.0000	7	0.0000	6	0.0000
6-8-43	4	0.0000	7	0.1429	5	0.0000
12-8-43	4	0.0000	5	0.0000	5	0.0000
19-8-43	2	0.0000	3	0.0000	5	0.0000
26-8-43	2	0.0000	3	0.0000	4	0.0000
2-9-43	1	0.0000	2	0.0000	3	0.0000
8-9-43	1	0.0000	2	0.0000	3	0.0000
16-9-43	1	0.0000	1	0.0000	3	0.0000
23-9-43	1	0.0000	1	0.0000	3	0.0000

TABLE V. 2

YEAR : 1944-45

Date	Co. 313		Co. 356		Co. 421	
	No. of clumps	Rate of emergence	No. of clumps	Rate of emergence	No. of clumps	Rate of emergence
27-4-44	102	0.0000	—	—	77	0.0000
5-5-44	97	0.0103	55	0.0182	68	0.0000
11-5-44	91	0.0989	51	0.1176	64	0.1406
18-5-44	82	0.6220	48	0.2083	60	0.3333
25-5-44	73	0.7671	43	0.4186	56	0.5000
1-6-44	68	0.6324	43	0.3256	51	0.3529
8-6-44	53	0.6792	36	0.2222	45	0.3111
15-6-44	38	0.6053	32	0.4063	43	0.6977
22-6-44	26	0.7231	26	0.4615	35	0.5758
29-6-44	20	0.6500	23	0.3913	30	0.7000
6-7-44	19	0.1053	23	0.0870	30	3.0667
13-7-44	17	0.0588	19	0.1053	29	0.0690
20-7-44	13	0.2308	15	0.1333	22	0.3182
27-7-44	7	0.1429	11	0.0909	10	0.2000
2-8-44	5	0.0000	8	0.0000	7	0.2857
10-8-44	3	0.0000	8	0.0000	5	0.2000
17-8-44	3	0.0000	8	0.0000	5	0.0000
24-8-44	3	0.0000	6	0.0000	3	0.0000
2-9-44	1	0.0000	5	0.0000	3	0.0000
7-9-44	1	0.0000	5	0.0000	3	0.0000
14-9-44	1	0.0000	5	0.0000	3	0.0000
21-9-44	1	0.0000	4	0.0000	3	0.0000
28-9-44			3			
6-10-44			3			

TABLE V. 3

YEAR : 1945-46

Date	Co. 313		Co. 356		Co. 421	
	No. of clumps	Rate of emergence	No. of clumps	Rate of emergence	No. of clumps	Rate of emergence
12-4-45	160	0.0000	108	—	158	0.0185
19-4-45	158	0.0633	107	0.0187	151	0.0949
26-4-45	148	0.1486	104	0.0096	141	0.0464
3-5-45	142	0.8169	99	0.2222	128	0.4326
10-5-45	131	0.7557	94	0.1848	115	0.5234
17-5-45	123	0.5935	86	0.3488	104	0.5391
24-5-45	107	0.5234	79	0.2405	82	0.3558
3-6-45	95	0.6842	68	0.3235	62	0.4634
7-6-45	72	0.7361	54	0.3519	54	0.5000
14-6-45	58	0.6551	45	0.2464	43	0.6481
21-6-45	47	1.0000	33	0.6667	35	0.6046
29-6-45	38	0.8947	31	0.4516	26	0.4571
6-7-45	27	0.2963	27	0.6296	19	0.19.23
13-7-45	23	0.1304	21	0.7143	16	0.0000
19-7-45	17	0.2941	18	0.2222	12	0.0000
26-7-45	14	0.1429	13	0.6154	11	0.1667
2-8-45	14	0.0714	12	0.5833	2	0.0000
9-8-45	12	0.0000	11	0.5455	2	0.0000
16-8-45	11	0.0909	9	0.4444	1	0.0000

TABLE V. 4

YEAR : 1946-47

Date	Co. 313		Co. 356		Co. 421	
	No. of clumps	Rate of emergence	No. of clumps	Rate of emergence	No. of clumps	Rate of emergence
25-4-46	137	0.3358	92	0.2717	130	0.1308
2-5-46	132	0.3939	88	0.1250	124	0.0806
9-5-46	121	0.2562	77	0.1558	117	0.1026
16-5-46	119	0.5363	77	0.2727	116	0.4224
23-5-46	110	0.5336	71	0.3945	114	0.6316
30-5-46	97	0.7216	69	0.3913	110	0.4273
6-6-46	85	0.3647	48	0.3958	82	0.4512
13-6-46	75	0.3867	39	0.1282	68	0.3382
20-6-46	70	0.1714	35	0.2286	59	0.0508
27-6-46	59	0.0508	33	0.1818	52	0.0769
4-7-46	55	0.0182	32	0.0938	44	0.1136
11-7-46	51	0.1176	29	0.2414	41	0.0976
18-7-46	48	0.0833	24	0.1667	30	0.1333
25-7-46	44	0.1818	22	0.4090	25	0.1600
8-8-46	33	0.1515	18	0.1667	20	0.0500
15-8-46	25	0.2000	17	0.1765	18	0.0556
22-8-46	21	0.0000	13	0.0769	10	0.0000
29-8-46	13	0.0000	11	0.2727	8	0.0000
5-9-46	9	0.1111	7	0.0000	5	0.0000
12-9-46	5	0.0000	2	0.5000	3	0.0000
19-9-46	1	0.0000	1	1.0000	3	0.0000

TABLE V. 5

YEAR : 1947-48

Date	Co. 313		Co. 356		Co.421	
	No. of clumps	Rate of emergence	No. of clumps	Rate of emergence	No. of clumps	Rate of emergence
7-5-47	33	0.0526	32	0.0313	48	0.1250
14-5-47	30	0.0000	26	0.7619	35	0.1429
21-5-47	28	0.0714	23	0.0870	33	0.0909
28-5-47	25	0.1600	23	0.0000	31	0.0000
4-6-47	21	0.0000	19	0.0000	19	0.0870
11-6-47	17	1.0000	15	0.0667	15	0.0667
18-6-47	15	0.0000	13	0.0000	11	0.0000
25-6-47	13	0.2380	9	0.1111	9	0.0000
2-7-47	9	0.2000	6	0.0000	6	0.0000
11-7-47	7	0.0000	4	0.0000	4	0.0000
18-7-47	4	0.2500	1	0.0000		
23-7-47	1	1.0000	1	0.0000		

TABLE V. 6

YEAR : 1948-49

Date	Co. 313		Co. 356		Co. 421	
	No. of clumps	Rate of emergence	No. of clumps	Rate of emergence	No. of clumps	Rate of emergence
20-4-48	52	0.1154	41	0.1220	48	0.8816
26-4-48	51	0.4118	40	0.2000	47	0.2128
5-5-48	44	0.4091	36	0.3611	43	0.2558
12-5-48	35	0.3143	28	0.1071	32	0.1563
19-5-48	32	0.2813	26	0.2692	27	0.2593
26-5-48	26	0.3077	22	0.0909	25	0.5200
2-6-48	24	0.2500	21	0.2857	19	0.7368
9-6-48	22	0.6364	17	0.1765	16	0.0625
16-6-48	17	0.1176	14	0.1429	15	0.0000
23-6-48	9	0.0000	11	0.0000	8	0.1250
30-6-48	4	0.0000	10	0.0000	6	0.1667
7-7-48	3	1.0000	10	0.8000	6	0.3333
15-7-48	2	0.0000	8	0.7500	3	0.1667
21-7-48	1	0.0000	5	1.0000	2	0.3333
28-7-48			5	0.6000	1	0.0000
4-8-48			2	0.5000	1	0.0000
11-8-48			2	0.5000	1	0.0000
18-8-48			1	0.0000	1	0.0000
25-8-48			1	0.0000	1	0.0000
1-9-48			1	0.0000		
8-9-48			1	0.0000		

TABLE V. 7

YEAR : 1949-50

Date	Co. 313		Co. 356		Co. 421	
	No. of clumps	Rate of emergence	No. of clumps	Rate of emergence	No. of clumps	Rate of emergence
26-4-49	70	0.5000	79	0.7595	50	0.3200
3-5-49	69	0.6522	77	0.6623	49	0.6122
10-5-49	59	0.7966	65	0.5077	43	0.3256
17-5-49	54	0.8148	61	0.8689	40	0.7750
25-5-49	38	0.6579	42	0.8587	29	0.5517
31-5-49	28	0.6071	27	0.5185	19	0.4211
8-6-49	24	0.7500	24	0.9583	18	0.5000
15-6-49	15	0.4000	16	0.5625	17	0.6471
21-6-49	7	0.0000	13	0.2308	14	0.1429
28-6-49	7	0.1429	13	0.1667	14	0.5000
5-7-49	5	0.2000	13	0.0767	14	0.6429
13-7-49	4	0.0000	11	0.4545	10	0.8000
22-7-49	4	0.0000	9	0.2222	10	0.2000
29-7-49	3	0.0000	8	0.0000	7	0.0000
3-8-49	3	0.0000	8	0.0000	7	0.0000
10-8-49	2	0.5000	5	0.0000	6	0.0000
18-8-49			2	0.0000	1	0.0000

TABLE V. 8

YEAR : 1950-51

Date	Co. 313		Co. 356		Co. 421	
	No. of clumps	Rate of emergence	No. of clumps	Rate of emergence	No. of clumps	Rate of emergence
1-5-50	64	0.2125	—	—	—	—
8-5-50	58	0.3750	36	0.4722	49	0.1837
15-5-50	47	0.5000	32	0.4375	48	0.2500
22-5-50	35	0.3617	25	0.2000	39	0.2821
30-5-50	27	0.8286	16	0.1875	33	0.4848
5-6-50	24	0.4815	13	0.5385	32	0.5625
13-6-50	17	0.7500	12	0.8333	28	0.5000
19-6-50	11	0.2941	10	0.7000	24	0.7083
26-6-50	11	0.0909	10	0.1000	21	0.1905
4-7-50	10	0.0000	10	0.0000	17	0.0000
11-7-50	8	0.3000	8	0.0000	17	0.0588
18-7-50	6	0.2500	6	0.0000	16	0.1250
24-7-50	2	0.0000	6	0.3333	12	0.0833
31-7-50	2	1.0000	4	0.0000	7	0.2857
8-8-50	1	0.0000	1	0.0000	5	0.0000
17-8-50	1	0.0000	1	0.0000	5	0.2000
22-8-50	1	0.0000	1	0.0000	4	0.2500
29-8-50	1	0.0000	1	0.0000		
5-9-50	1	0.0000				
11-9-50	1	0.0000				

TABLE V. 9

YEAR : 1951-52

Date	Co. 313 No. of clumps	Co. 313 Rate of emergence	Co. 356 No. of clumps	Co. 356 Rate of emergence	Co. 421 No. of clumps	Co. 421 Rate of emergence
21-5-51	38	0.7632	51	0.3922	47	0.6170
28-5-51	31	0.2581	35	0.3143	30	0.4667
4-6-51	26	0.5000	27	0.2593	23	0.3913
11-6-51	23	0.3043	23	0.1739	19	0.1579
18-6-51	22	0.6818	23	0.5652	19	0.4211
25-6-51	20	0.2000	23	0.3478	16	0.2500
3-7-51	18	0.5000	22	0.6818	13	0.6154
11-7-51	17	0.2353	13	0.2308	13	0.1538
18-7-51	12	0.6667	10	0.5000	12	0.0833
24-7-51	8	0.8750	9	0.4444	11	0.2727
30-7-51	4	1.2500	3	0.0000	6	0.5000
7-8-51	1	0.0000	3	0.0000	4	0.0000
13-8-51	1	1.0000	3	0.0000	4	0.0000
21-8-51			2	0.0000	3	0.0000
27-8-51			1	0.0000		

EFFECTIVE COMPENSATION

It has been noticed that tillers emerging after September do not generally result in millable shoots. The extra emergences after September do not, therefore, contribute towards effective compensation. The resultant extra emergences have been divided into two parts—emergences upto September and those after September. These are shown in Table VI.

TABLE VI

SHOWING EXTRA EMERGENCES UPTO SEPTEMBER AND AFTER SEPTEMBER

Seasons	Co. 313 Emergence Upto Sept.	Co. 313 Emergence After Sept.	Co. 356 Emergence Upto Sept.	Co. 356 Emergence After Sept.	Co. 421 Emergence Upto Sept.	Co. 421 Emergence After Sept.
1942-43	4	0	18	2	6	-2
1943-44	55	33	34	21	31	15
1944-45	26	12	35	2	35	11
1945-46	196	7	251	26	229	28
1946-47	95	66	60	34	108	10
1947-48	11	0	51	0	42	0
1948-49	50	-2	55	9	13	1
1949-50	8	7	81	8	17	11
1950-51	31	8	13	7	37	-1
1951-52	24	0	55	5	29	5

The number of extra emergence after September had been maximum during 1946-47 in Co. 313 and Co. 356 and during 1945-46 in Co. 421. The number had been fairly considerable in all the three varieties during 1943-44 also.

The rates of effective compensation are shown below (Table VII) expressed as percentages of the total mortalities.

TABLE VII

SHOWING EFFECTIVE COMPENSATION

Seasons	Co. 313	Co. 356	Co. 421
1942-43	6.54	35.33	11.25
1943-44	9.89	8.44	8.01
1944-45	9.18	29.62	23.54
1945-46	36.51	116.61	56.24
1946-47	18.92	23.11	37.35
1947-48	7.95	69.03	43.18
1948-49	24.44	52.36	10.65
1949-50	1.84	41.67	14.39
1950-51	70.98	45.20	76.18
1951-52	27.01	47.02	40.86

The Table shows that the order of effective compensation varies from 1.84% to 70.98 %, 8.44 % to 116.61 % and 8.01 % to 76.18 % in Co. 313, Co. 356 and Co. 421 respectively. Co. 356 has mostly recorded highest compensation. The effective compensations in Co. 421 are generally higher than those of Co. 313. The maximum compensations of 70.98 % and 76.18 % have been obtained for varieties Co. 313 and Co. 421 during 1950-51 and of 116.61 % for variety Co. 356 during the season 1945-46.

PERIODIC FLUCTUATIONS IN COMPENSATION

The resultant extra emergence that accrued for the entire season has been split up into its respective monthly components to study the nature of periodic variations. These have been expressed as percentages of the total mortalities and are presented in Table VIII. They have also been depicted in Figs 2.1 to 2.5.

A scrutiny of the Table reveals the absence of a periodic trend from season to season. The reason may probably be ascribed to the fact that compensation obtained in any month is the resultant of a number of complex factors, the most important being micro-and macro-climatic conditions and intensity of pest activities, the distributions of which over the different months are never similar from season to season. The varieties also do not exhibit similar trends from month to month. It might possibly be due to the existence of interaction.

TABLE VIII

SHOWING PERCENTAGE COMPENSATION DURING DIFFERENT MONTHS

Month	1943-44	1944-45	1945-46	1946-47	1947-48	1948-49	1949-50	1950-51	1951-52
					Co. 313				
April	—	—	0.50	2.10	—	2.99	0.64	—	—
May	(-)2.35	1.29	(-)3.67	(-)1.11	15.95	8.31	(-)4.38	(-)25.27	3.87
June	7.76	(-)5.36	16.26	6.43	0.15	2.88	3.99	33.27	(-)12.86
July	3.47	5.40	9.69	4.21	1.50	7.18	1.63	3.47	15.35
August	0.54	2.36	11.99	9.22	(-)9.65	1.11	3.80	53.27	18.16
Sept.	4.08	5.49	1.68	(-)2.13	—	1.97	(-)0.96	6.24	2.51
Oct.	1.48	4.38	0.37	10.87	—	(-)0.91	1.17	17.98	(-)0.09
Nov.	0.80	—	1.12	2.18	—	—	2.77	—	—
Total	15.78	13.56	37.94	31.77	7.95	23.53	8.66	88.96	27.12
					Co. 356				
April	—	—	1.77	0.11	—	1.46	2.21	—	—
May	(-)5.58	11.71	7.46	3.31	24.98	17.25	(-)2.61	(-)12.94	9.06
June	3.02	(-)2.45	45.11	8.24	21.87	7.79	13.88	16.06	16.25
July	10.83	7.55	4.83	2.07	19.52	6.08	14.77	(-)8.67	14.73
Aug.	0.51	9.65	27.85	5.88	2.71	6.99	13.45	36.18	5.57
Sept.	5.11	3.17	29.59	5.12	—	12.80	0.00	14.57	1.41
Oct.	4.71	1.56	11.63	10.85	—	1.10	3.42	15.48	3.11
Nov.	4.24	—	—	2.75	—	7.76	0.52	6.89	1.72
Total	22.84	31.19	128.24	38.33	69.08	61.23	45.64	67.57	51.85
					Co. 421				
April	—	—	1.40	0.83	—	0.52	3.10	—	—
May	(-)0.15	6.54	(-)0.43	4.40	30.72	4.91	20.61	24.14	14.96
June	3.00	(-)4.61	20.80	5.70	5.26	6.60	(-)6.52	18.96	3.99
July	1.42	10.56	10.49	5.49	14.64	(-)8.93	(-)4.19	3.17	14.54
Aug.	0.52	6.46	22.48	12.07	(-)7.45	3.73	1.99	15.47	7.25
Sept.	3.22	4.59	1.51	8.99	—	3.83	(-)0.59	14.29	1.48
Oct.	3.12	7.02	8.85	1.60	—	0.58	8.02	(-)1.02	4.38
Nov.	0.91	—	(-)1.84	1.75	—	0.03	1.64	(-)0.75	1.43
Total	12.04	30.56	63.26	40.83	43.17	11.27	24.06	74.26	48.03

N.B.—Negative sign indicates that the rate of emergence shown by the affected clumps has been lower than the normal rate.

MORTALITY AND EXTRA EMERGENCE

An examination of the figures of mortalities due to borer infestation and estimates of resultant extra emergence obtained during different seasons in respect of the three varieties furnished in Table II will show that the number of extra emergences increases with increase in the number of mortalities. The rate of increase is slow in the beginning, but is accelerated with increase in mortalities. An exponential curve of the type of $y = a\, e^{bx}$ has been fitted to these figures, the equation to which has worked out as follows :

$$y = 18.88\ e^{.004168x}$$

where y = no. of mortalities due to borers and

x = no. of extra emergence subsequent to mortality due to borers.

The exponential coefficient has come out significant indicating that the curve has been a good fit in respect of the observed values. The curve has been depicted in figure (3) with the observed values indicated by means of dots. With the help of this equation the expected number of extra emergence by way of compensation have been calculated for different levels of mortalities and are shown in Table IX:

TABLE IX

SHOWING EXPECTED NUMBER OF EXTRA EMERGENCE FOR VARYING NUMBER OF MORTALITIES

Mortality	Extra emergence
50	23.2
100	28.6
150	35.3
200	43.5
250	53.6
300	65.9
350	81.3
400	100.0
450	123.3
500	151.7
550	187.1
600	230.1

ESTIMATION OF COMPENSATION INDEX IN WEIGHT

The method adopted for estimation of compensation in weight is as follows :

Let N denote the number of mother plants that died due to attack of borers ;

N_k denote the number of tillers that emerged in the kth week and died subsequently due to attack of borers ;

n_k denote the number of extra emergences in the kth week.

Also let w_k denote the average weight at harvest of tillers that emerged in the k_{th} week ;

and $\bar{w}$ the average weight at harvest of mother plants.

Evidently, the expected total weights at harvest of tillers emerging in the 1st, 2nd,......... weeks and dying subsequently are

$$N_1 \mathrm{x}\, \bar{w}_1,\ N_2 \mathrm{x}\, \bar{w}_2, \ldots\ldots\ldots, N_k \mathrm{x}\, \bar{w}_k, \ldots\ldots$$

Therefore, total loss in weight due to attack of borers is equal to

$$N \mathrm{x}\, \bar{w} + (N_1 \mathrm{x}\, \bar{w}_1 + N_2 \mathrm{x}\, \bar{w}_2 + \ldots\ldots\ldots + N_k \mathrm{x}\, \bar{w}_k + \ldots\ldots)$$

or equal to

$$W = N \mathrm{x}\, \bar{w} + \Sigma N_k \mathrm{x}\, \bar{w}_k \quad (k = 1,2,\ldots\ldots) \ldots\ldots (A)$$

Again the total weights at harvest of tillers (extra emergence) emerging in the 1st 2nd, ... weeks, subsequent to dead-heart occurrence, are

$$n_1 \mathrm{x}\, \bar{w}_1,\ n_2 \mathrm{x}\, \bar{w}_2, \ldots\ldots, n_k \mathrm{x}\, \bar{w}_k, \ldots\ldots$$

Therefore, total gain in weight due to extra emergence is given by

$$C = n_1 \mathrm{x}\, \bar{w}_1 + n_2 \mathrm{x}\, \bar{w}_2 + \ldots\ldots\ldots + n_k \mathrm{x}\, \bar{w}_k + \ldots\ldots$$

$$= \Sigma_k n_k \mathrm{x}\, w_k \qquad (= 1, 2, \ldots\ldots) \ldots\ldots\ldots (B)$$

Hence, the index of compensation (in weight)

$$I = \frac{C}{W} \mathrm{x}\, 100$$

The estimates of indices of compensation have been worked out according to the above method in respect of all the seasons under consideration and are furnished in Table X. Average weights of tillers of different age-groups have been found out by means of linear regression.

TABLE X

SHOWING PERCENTAGE COMPENSATION IN WEIGHT BY EXTRA-EMERGENCE

Season	Varieties		
	Co. 313	Co. 356	Co. 421
1943-44	12.32	6.79	6.16
1944-45	7.74	24.65	18.10
1945-46	26.12	71.03	41.94
1946-47	23.01	20.77	50.35
1947-48	14.56	44.06	31.58
1948-49	22.32	50.02	11.68
1949-50	3.04	31.12	18.29
1950-51	54.46	31.36	51.75

It will be seen from the above Table that compensation percentages have varied considerably from season to season, the range of variation being from 3.04 to 54.46 in Co. 313, from 6.79 to 71.03 in Co. 356 and from 6.16 to 51.75 in Co. 421. The results are similar to those of compensation in tillers, variety Co. 356 recording highest compensation in most of the seasons followed by Co. 421.

TABLE XI

SHOWING PERCENTAGE COMPENSATION IN WEIGHT DURING DIFFERENT MONTHS

	1943-44	1944-45	1945-46	1946-47	1947-48	1948-49	1949-50	1950-51	1951-52
				Co. 313					
April	—	—	0.61	2.41	—	3.51	0.74	—	—
May	(-)2.48	1.61	(-)3.47	(-)1.22	13.82	8.93	(-)4.58	(-)26.00	4.37
June	7.58	(-)6.16	13.59	6.18	0.59	2.74	3.35	30.87	(-)12.45
July	2.77	5.18	7.98	3.60	2.08	5.86	1.11	0.73	11.25
August	0.41	1.84	6.41	6.81	(-)1.93	0.77	2.16	36.59	9.08
Sept.	2.77	3.58	1.18	(-)1.43	—	0.89	(-)0.52	3.24	0.88
Oct.	0.87	1.69	0.20	5.71	—	(-)0.38	0.32	9.03	0.02
Nov.	0.40	—	0.23	0.95	—	—	0.46	—	—
Total	12.32	7.74	26.12	23.01	14.56	22.32	3.04	54.46	13.15
				Co. 356					
April	—	—	1.94	0.11	—	2.10	2.33	—	—
May	(-)4.04	13.35	6.75	2.92	22.65	20.46	(-)2.50	(-)14.40	9.92
June	1.87	(-)2.19	34.12	6.59	12.82	10.59	11.68	17.55	15.71
July	5.73	5.67	2.80	1.44	8.08	3.13	10.30	(-)7.52	11.18
August	0.24	6.02	12.95	2.96	0.51	4.98	8.12	22.84	3.55
Sept.	1.54	1.55	10.08	2.11	—	6.50	—	6.65	0.87
Oct.	1.01	0.25	2.39	3.90	—	0.38	1.10	5.08	0.32
Nov.	0.44	—	—	0.74		1.88	0.09	1.16	—
Total	6.79	4.65	71.03	20.77	44.06	50.02	31.12	31.30	41.55
				Co. 421					
April	—	—	1.77	1.21	—	0.70	3.59	—	—
May	(-)0.11	8.77	(-)0.18	6.39	27.31	6.20	21.17	22.02	14.84
June	2.34	(-)5.46	17.92	7.64	2.75	7.03	(-)5.56	16.33	3.96
July	1.05	8.84	7.69	6.89	1.50	(-)7.79	(-)3.04	1.81	9.55
August	0.31	4.13	12.58	14.63	0.02	2.96	1.03	7.22	2.96
Sept.	1.51	1.67	0.61	10.13	—	2.22	(-)0.21	4.63	0.67
Oct.	0.90	0.15	1.59	1.75	—	0.27	1.30	(-)0.19	0.46
Nov.	0.16	—	(-)0.04	1.71	—	0.09	0.01	(-)0.07	0.02
Total	6.16	18.10	41.94	50.35	31.58	11.68	18.29	51.75	32.46

Negative sign indicates that the rate of emergence shown by affected clumps has been lower than the normal rate.

TABLE XII

SHOWING THE MEAN NUMBER OF MORTALITIES DUE TO BORER AND EMERGENCES PER PLOT

	Co. 313		Co. 356		Co. 421		Mean	
	No. of emergences	No. of mortalities	No. of emergences	No. of mortalities	No. of emergences	No. of mortalities	No. of emergences	No. of mortalities
1943-44	163.6	69.4	129.3	50.0	135.3	48.1	142.6	55.8
1944-45	145.9	35.0	48.8	14.8	101.0	18.8	102.7	22.8
1945-46	242.1	67.0	153.6	26.9	195.6	50.9	197.1	48.3
1946-47	207.6	62.6	111.2	30.0	148.4	36.0	155.8	43.1
1947-48	35.0	16.9	13.3	9.3	24.6	12.1	24.3	12.8
1948-49	203.3	50.8	130.5	26.3	145.3	30.3	159.7	35.8
1949-50	216.9	21.9	200.4	24.3	177.0	14.8	198.1	20.3
1950-51	155.0	6.3	136.7	4.9	138.9	6.4	143.5	5.9
1951-52	147.9	11.0	163.4	14.5	139.8	8.8	150.3	11.4
Mean	157.5	37.9	120.8	22.3	134.0	25.1	141.6	28.5

Information in respect of compensation during different months has been furnished in Table XI. It is noticed that there is no regular trend from month to month but maximum compensation in weight has mostly accrued either in May, June or July.

VARIATION IN TILLERING AND MORTALITY

The mean number of mortalities due to borer incidence and emergences per plot under the three varieties obtained during the different seasons (1943-44 to 1951-52) have been presented in Table XII.

An examination of the Table will show that there exists a high positive correlation between emergence and mortality. Variety Co. 313 has shown the highest emergence as well as mortality, whereas Co. 356 has recorded the minimum.

INFLUENCE OF AGE OF TILLERS ON WEIGHT AND JUICE QUALITY

The canes which were entirely healthy all through the season were selected for this study. The weeks were serially numbered starting from the initial week of observation, and the regression coefficients (b_{21} and b_{31}) of weight (2) and Brix % (3) on the time of emergence (i) have been worked out for the three varieties. The values of the regression coefficients obtained during the different seasons are shown below (Table XIII). The corresponding observed values of " t " have also been furnished against each of the regression coefficients.

TABLE XIII

SHOWING THE REGRESSION COEFFICIENTS B_{21} AND B_{31}
1 = TIME OF EMERGENCE ; 2 = WEIGHT ; 3 = BRIX %

Season	b_{21}	t	b_{31}	t
		Co. 313		
1943-44	-0.2395	2.0754*	-0.2070	2.7345*
1944-45	-0.5375	10.6369**	-0.4366	13.2015**
1945-46	-0.3013	6.0378**	-0.2866	9.3097**
1946-47	-0.1913	5.7447**	-0.1460	4.7557**
1947-48	-0.1472	1.7156	0.0141	0.3681
1948-49	-1.0451	5.2334**	-0.1901	5.3249**
1949-50	-0.5527	2.6120*	-0.1819	2.4286*
1950-51	-0.6506	3.4494**	-0.2050	4.2094**
1951-52	-0.7763	6.2903**	-0.6808	6.8956**
Pooled	-0.3923		-0.1471	

TABLE XIII—(Contd.)

Season	b_{21}	t	b_{31}	t
		Co. 356		
1943-44	-0.4994	4.7607**	-0.2266	6.6647**
1944-45	-1.1165	5.5027**	-0.3506	11.0599**
1945-46	-0.2980	5.6439**	-0.3120	5.9203**
1946-47	-0.2736	4.4852**	-0.0725	2.9713*
1947-48	-0.1396	1.2450	-0.0521	1.2230
1948-49	-1.0382	5.4931**	-0.4056	10.6178**
1949-50	-0.5649	3.2428**	0.0306	0.6362
1950-51	-0.9871	5.9716**	-0.1690	7.0711**
1951-52	-0.9692	12.6963**	-0.2436	2.5090*
Pooled	-0.8818		-0.2928	
		Co. 421		
1943-44	-0.5039	3.1009**	-0.0984	1.3103
1944-45	-1.2136	7.6956**	-0.2819	9.1824**
1945-46	-0.3501	6.4954**	-0.2698	8.1021**
1946-47	-0.0669	1.4575	0.0053	0.1699
1947-48	-0.1728	1.7092	-0.0112	0.6054
1948-49	-1.3859	4.5099**	-0.4417	5.6268**
1949-50	-0.8916	5.2633**	-0.1734	6.5682**
1950-51	-0.9337	6.1916**	0.0243	0.5412
1951-52	-0.8300	4.9405**	-0.6263	13.1577**
Pooled	-0.8314		-0.2172	

* Indicates significance at 5 % level.

** Indicates significance at 1 % level.

An examination of the data will show that the regression coefficients have come out non-significant only during 1947-48 for all three varieties and during 1946-47 for Co. 421. The values of b_{31} during 1943-44 and 1950-51 for Co. 421 and during 1949-50 for Co. 356 are also non-significant. Barring these, all the other coefficients are significant and negative, indicating that age of tiller profoundly affects its weight and juice quality. The later tillers emerge, the less they put in weight and juice quality.

The data for the different seasons in respect of each variety have been pooled together. The sums of squares and sums of products have been found out by the method of analysis of variance, the structure of which works out as follows :—

Variations due to	D.F.	Σ_{11}	Σ_{22}	Σ_{33}	Σ_{12}	Σ_{13}
Between seasons	S-1	$\sum_i n_i(\bar{x}_{1i}-\bar{x}_{1\cdot\cdot})^2$	$\sum_i n_i(\bar{x}_{2i}-\bar{x}_{2\cdot\cdot})^2$	$\sum_i n_i(\bar{x}_{3i\cdot}-\bar{x}_{3\cdot\cdot})^2$	$\sum_i n_i(\bar{x}_{1i\cdot}-x_{1\cdot\cdot})(\bar{x}_{2i\cdot}-x_{2\cdot\cdot})$	$\sum_i n_i(x_{1i\cdot}-x_{1\cdot\cdot})(x_{3i\cdot}-\bar{x}_{3\cdot\cdot})$
Within seasons	$\sum_i S(n_i-1)$	$\sum_{ij}\sum(x_{1ij}-\bar{x}_{1i\cdot})^2$	$\sum_{ij}\sum(x_{2ij}-\bar{x}_{2i})^2$	$\sum_{ij}\sum(x_{3ij}-\bar{x}_{3i})^2$	$\sum_{ij}\sum(x_{1ij}-\bar{x}_{1i})(x_{2ij}-x_{2i})$	$\sum_{ij}\sum(x_{1ij}-\bar{x}_{1i\cdot})(x_{3ij}-\bar{x}_{3i})$

where n_i denotes the number of observation in the i^{th} season ($i = 1,2,\ldots\ldots S$), $\bar{x}_{1i\cdot}$, etc. denote the means of the respective variate in the i^{th} season, $\bar{x}_{1\cdot}$, etc. denote the general means of the respective variate, x_{1ij}, etc. denote the j^{th} observation of the i^{th} season.

The pooled regression coefficients have been calculated with the "within seasons" sums of squares and sums of products. These are shown at the foot of the Table for each variety. The average difference in weight (in ozs.) due to difference of one week in emergence ranges between -0.3923 and -0.8818 and that of brix % varies from -0.1417 to -0.2928 units for the three varieties. Variety Co. 356 has recorded the maximum values, followed by Co. 421.

EFFECT OF BORER INFESTATION ON WEIGHT AND JUICE QUALITY OF CANES

At the time of harvest, all the clumps available in the experimental plots were dug out ; each cane was stripped off and split up longitudinally. The length of each cane, total number of joints, weight, Brix % (Hand refractometer) and the length infested by borers, if any, were recorded plotwise. These data collected during the ten successive seasons, 1943-44 to 1951-52 have been examined to study the effect of borer infestation on weight and juice quality of sugarcane.

The results of analyses of variance have been presented in Tables XIV.1, XIV.2 and XIV. 3.

It will be seen that healthy canes have recorded, on an average, higher weights than canes infested with top borer in all the seasons, although the differences are statistically significant only during 1944-45 and 1949-50 ; but Brix values of healthy canes have been lower than those of affected canes in some of the seasons, the differences being always non-significant. It is further seen that canes affected by stem borer have recorded lower weights than healthy canes in all the three seasons during which these were available in sufficient numbers, the difference being significant only during 1951-52. Juice quality of healthy canes has also been significantly better than that of stem-borer affected canes during the two seasons 1943-44 and 1951-52. An examination of Table 1.3, furnishing the results in respect of root borer infestation will show that the differences are always non-significant both for weight and Brix %.

The results of combined analyses have been set out in Tables XV.1, XV.2 and XV.3.

TABLE XIV. 1.

SHOWING MEAN WEIGHT PER CANE AND BRIX % OF HEALTHY AND TOP BORER AFFECTED CANES

Season	Varieties	Weight per cane (oz.)		Brix %	
		Healthy	Affected	Healthy	Affected
1943-44	Co. 313	11.92	8.94	20.04	16.64
	Co. 356	16.92	14.76	21.26	21.54
	Co. 421	14.86	15.50	19.66	19.70
	Mean	14.58	13.07	20.32	20.29
	Diff.	1.51		0.03	
	S.E.	±0.61		±0.17	
1944-45	Co. 313	22.73	21.45	19.83	20.38
	Co. 356	28.05	24.80	19.70	20.48
	Co. 421	26.60	21.45	18.78	19.13
	Mean	25.79	22.57	19.43	20.00
	Diff.	3.22*			0.57
	S.E.	±1.06		±0.20	
1946-47	Co. 313	5.52	5.63	18.02	19.45
	Co. 356	8.95	6.16	19.30	18.92
	Mean	7.23	5.90	18.66	19.18
	Diff.	1.33			0.46
	S.E.	±0.58		±0.31	
1947-48	Co. 313	7.62	6.94	14.38	14.56
	Co. 356	8.34	8.02	14.38	14.56
	Mean	7.98	7.48	14.38	14.56
	Diff.	0.50			0.18
	S.E.	±0.62		±0.37	
1949-50	Co. 313	16.56	16.52	18.27	18.42
	Co. 356	22.70	13.66	19.90	19.38
	Co. 421	21.34	16.84	19.42	19.30
	Mean	20.20	15.67	19.20	19.03
	Diff.	4.53**		0.17	
	S.E.	±1.10		±0.65	
1950-51	Co. 313	18.39	17.98	17.04	17.89
	Co. 356	22.24	19.00	17.60	16.50
	Co. 421	18.80	15.65	18.13	17.14
	Mean	19.81	17.54	17.59	17.18
	Diff.	2.27		0.41	
	S.E.	±0.99		±0.83	

* Indicates significance at 5 % level.

** Indicates significance at 1 % level.

TABLE XIV. 2.

SHOWING MEAN WEIGHT PER CANE AND BRIX % OF HEALTHY AND STEM BORED CANES

Season	Varieties	Weight per cane (oz.) Healthy	Weight per cane (oz.) Affected	Brix % Healthy	Brix % Affected
1943-44	Co. 313	10.78	9.98	20.23	17.75
	Co. 356	16.66	14.34	22.33	19.54
	Co. 421	14.20	14.12	19.79	18.30
	Mean	13.86	12.81	20.45	18.53
	Diff.	1.05		1.92**	
	S.E.	±0.39		±0.23	
1950-51	Co. 313	17.80	17.50	20.80	20.36
	Co. 356	19.20	12.30	20.60	20.36
	Co. 421	21.50	18.50	20.70	20.34
	Mean	19.50	18.50	20.50	20.35
	S.E.	±1.74		±0.31	
1951-52	Co. 313	18.39	14.96	17.18	14.92
	Co. 356	22.24	15.30	17.78	15.28
	Co. 421	18.80	15.80	18.36	16.83
	Mean	19.81	15.35	17.77	15.67
	Diff.	4.46**		2.10**	
	S.E.	±0.77		±0.21	

** Indicates significance at 1 % level.

TABLE XIV. 3.

SHOWING MEAN WEIGHT PER CANE AND BRIX % OF HEALTHY AND ROOT BORER AFFECTED CANES

Season	Varieties	Weight per cane (oz.) Healthy	Weight per cane (oz.) Affected	Brix % Healthy	Brix % Affected
1944-45	Co. 313	20.46	19.00	20.14	20.10
	Co. 356	24.36	21.66	19.68	19.80
	Co. 421	26.56	23.50	18.84	19.04
	Mean	23.46	21.69	19.55	19.65
	Diff.	1.77			0.10
	S.E.	±0.89		±0.18	
1945-46	Co. 313	8.08	7.47	20.97	20.00
	Co. 356	4.48	4.45	17.62	18.52
	Co. 421	6.11	5.88	17.18	17.28
	Mean	6.22	5.99	18.59	18.58
	Diff.	0.27		0.01	
	S.E.	±0.38		±0.47	
1949-50	Co. 313	17.37	16.50	18.56	18.20
	Co. 356	17.60	17.23	19.03	19.21
	Co. 421	20.93	17.00	19.02	19.16
	Mean	18.63	16.91	18.87	18.86
	Diff.	1.72		0.01	
	S.E.	±0.56		±0.26	
1950-51	Co. 313	20.80	25.20	19.72	20.54
	Co. 356	25.00	26.13	19.78	20.55
	Co. 421	25.17	24.20	20.18	20.70
	Mean	23.66	25.18	19.90	20.60
	Diff.		1.52		0.70
	S.E.	±1.01		±0.24	
1951-52	Co. 313	16.93	16.84	20.78	20.81
	Co. 356	17.50	16.86	20.55	20.38
	Co. 421	16.95	16.08	21.35	21.12
	Mean	17.13	16.59	20.89	20.77
	Diff.	0.54		0.12	
	S.E.	±0.63		±0.16	

TABLE XV. 1.

SHOWING THE RESULTS OF COMBINED ANALYSES CONTRAST : HEALTY vs. TOP BORER AFFECTED CANES

Variation due to	Degrees of freedom	Sums of squares	Mean sums of squares	Variance Ratio
	Weight per cane			
Total	131	5453.74		
Replication	18	612.16		
Season	3	1440.02		
Variety	2	236.97	118.48	
Season × Variety	6	144.99	24.17	
Healthy vs. Affected	1	255.65	255.65	8.95**
Season × Healthy vs. Affected	3	39.25	13.08	
Variety × Healthy vs. Affected	2	58.67	29.34	
Season × Variety × Healthy vs. Affected	6	96.39	16.07	
Error	90	2569.64	28.55	
	Brix %			
Total	119	319.40		
Replication	16	48.71		
Season	3	160.69		
Variety	2	8.74	4.37	
Season × Variety	6	27.73	4.62	
Healthy vs. Affected	1	0.11	0.11	
Season × Healthy vs. Affected	3	3.51	1.17	
Variety × Healthy vs. Affected	2	1.99	1.00	
Season × Variety × Healthy vs. Affected	6	6.66	1.11	
Error	80	61.26	0.77	

** Indicates significance at 1 % level.

TABLE XV. 2.

SHOWING THE RESULTS OF COMBINED ANALYSES CONTRAST : HEALTHY vs. STEM-BORED CANES

Variation due to	Degrees of freedom	Sums of squares	Mean sums of squares	Variance Ratio
	Weight per cane			
Total	95	2673.74		
Replication	13	622.48		
Season	2	470.77		
Variety	2	130.67	65.34	5.17
Season × Variety	4	246.58	61.64	4.88
Healthy vs. Affected	1	180.95	180.95	14.33**
Season × Healthy vs. Affected	2	70.04	35.02	2.77
Variety × Healthy vs. Affected	2	97.28	48.64	3.85
Season × Variety × Healthy vs. Affected	4	34.53	8.63	
Error	65	821.14	12.63	
	Brix %			
Total	113	550.62		
Replication	16	35.11		
Season	2	281.82		
Variety	2	16.22	8.11	7.31
Season × Variety	4	26.58	6.65	5.99
Healthy vs. Affected	1	79.67	79.67	71.77**
Season × Healthy vs. Affected	2	17.72	8.86	7.98
Variety × Healthy vs. Affected	2	3.99	1.99	1.79
Season × Variety × Healthy vs. Affected	4	0.96	0.24	
Error	80	88.55	1.11	

**Indicates significance at 1 % level.

TABLE XV. 3

SHOWING THE RESULTS OF COMBINED ANALYSES
CONTRAST : HEALTHY vs. ROOT BORER AFFECTED CANES

Variations due to	Degrees of freedom	Sums of squares	Mean sums of squares	Variance Ratio
	Weight per cane			
Total	149	8938.67		
Replication	20	1701.97		
Season	4	6159.48		
Variety	2	14.94	7.47	
Season × Variety	8	189.36	23.67	3.04
Healthy vs. Affected	1	13.75	13.75	1.77
Season × Healthy vs. Affected	4	37.53	9.38	
Variety × Healthy vs. Affected	2	14.26	7.13	1.20
Season × Variety × Healthy vs. Affected	8	28.20	3.53	
Error	100	779.18	7.79	
	Brix %			
Total	149	436.06		
Replication	20	76.74		
Season	4	123.93		
Variety	2	17.26	8.63	6.03
Season × Variety	8	66.26	8.28	5.79
Healthy vs. Affected	1	0.13	0.13	
Season × Healthy vs. Affected	4	2.37	0.59	
Variety × Healthy vs. Affected	2	1.39	0.70	
Season × Variety × Healthy vs. Affected	8	4.52	0.57	
Error	100	143.46	1.43	

It is seen that the contrast Healthy vs. Affected is highly significant only for weight in case of Top-borer ; both for weight and juice quality in case of Stem-borer, whereas it is non-significant for both the characters in respect of Root borer. The above results, therefore, indicate that top borer infestation has profoundly adverse effects on weight of cane; that of stem borer both on weight and juice quality ; whereas root borer infestation has no significant effect either on weight or on juice-quality.

The data were further scrutinized to study the effect of degree of infestation on weight and juice quality for which purpose, partial correlation coefficients $(r_{12\cdot34})$ between weight and Brix % (1) and length of cane infested by borers (2) after keeping constant the total length (3) and age (4) of cane, were found out separately for each borer. The values of these partial correlation coefficients have in all cases been found to be very small, almost equal to zero. The results, therefore, suggest that either loss in weight and juice quality is independent of degree of infestation, or the small variations in length of canes infested obtained in the data are not sufficient to produce considerable changes in the characters so as to outweigh the sampling fluctuations, thus necessitating further examination of data comprising a more comprehensive universe of infestations.

SUMMARY OF RESULTS

1. Weekly records of emergences, dead-heart occurrences and mortalities due to sugarcane borers in respect of varieties Co. 313, Co. 356 and Co. 421 collected at Pusa during the ten successive seasons 1942-43 to 1951-52 with a view to studying the phenomenon of compensatory tillering following dead-heart occurrence or mortality due to borers have been critically examined.

2. The clumps available in the different varieties have been divided into the following three categories :

Class I : Clumps which had emergence subsequent to dead-heart occurrence or mortality due to borers.

Class II : Clumps which had no emergence following dead-heart occurrence or mortality due to borers.

Class III : Clumps which remained healthy all through i.e. free from borer infestation.

Clumps under Class II cannot afford any compensation as they did not show any emergence subsequent to dead-heart occurrence. It is the clump under Class I which can possibly compensate for the loss of shoots sustained by both the categories.

3. For the purpose of defining normal emergence, a clump has been reckoned as healthy upto the week of dead-heart occurrence or mortality. The rates of emergence of clumps under Class I during different weeks have been evaluated and compared with the corresponding normal rates of emergence. It has been found that these rates are somewhere higher and somewhere lower than normal rates. The difference between these two rates multiplied by the corresponding number of affected clumps showing emergences would obviously furnish evidence of compensatory tillering. The resultants calculated over the entire season gave unequivocal indications of extra tillers following dead-heart occurrence in all the three varieties during all the ten seasons.

4. The resultant extra emergences have been expressed as percentages of the total loss of shoots suffered by the affected clumps under both the classes to get the indices of compensation. Compensation indices have varied from season to season and from variety to variety. Co. 356 has generally recorded maximum compensation. Co. 421 occupies the intermediate position in this respect. Compensation percentages have ranged between 0.88 % to 128.23 % under the three varieties during the three seasons.

5. Tillers emerging after September mostly result in non-millable shoots. Tillers emerging after September have therefore been excluded in the estimation of " Effective Compensation ". The orders of effective compensation obtained for the three varieties have ranged between 1.84 % to 116.61 % during the different seasons.

6. A scrutiny of values of percentage compensation obtained for different months revealed the absence of a periodic trend from season to season.

7. Increase in the intensity of mortality is followed by an increase in extra emergence. An exponential curve after type $y = ae^{bx}$, where y stands for extra emergence and x for mortality, has been fitted with the help of this equation, the expected number of extra emergences for different levels of mortalities have been calculated.

8. Estimates of compensation percentage in weight have varied between 3.04 and 54.46 in Co. 313, from 6.79 to 71.03 in Co. 356 and from 6.16 to 51.75 in Co. 421.

9. A high positive correlation has been found to exist between mortalities due to borers and emergences. The seasonal and varietal differences in respect of these two have come out highly significant.

10. Age of tillers exerts a profound influence on weight and juice quality. The later tillers emerge, the less they put in weight and quality. The average differences in weight and Brix % of tillers due to a difference of one week in emergence have varied from −0.3923 to −0.8818 oz. and −0.1417 to −0.2928 unit respectively for the three varieties.

11. Analysis of harvest data has indicated that top borer infestation adversely affects weight of canes, that of stem borer both weight and juice quality whereas root borer infestation has no significant effect either on weight or quality of canes. Partial correlation coefficients between intensity of infestation as measured by percentage length of canes infested on the one hand and weight and juice quality on the other (keeping age and length of canes constant) have come out very low and non-significant for the three borers.

ACKNOWLEDGMENT

The work was carried out as part of the scheme of Sugarcane Research in Bihar financed jointly by the State Government and the Indian Central Sugarcane Committee to whom grateful thanks are due. The author is also indebted to Dr. K. S. Bandyopadhya and Shri R. C. Acharya for the statistical analysis of the voluminous data and the staff of the Insect Pest Scheme for the collection and collation of field records.

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DISCUSSION

Mr. A. N. Kalra and Mr. B. D. Gupta enquired as to what was the maximum extent of compensation which the extra tillering could offer as a result of borer attack so that the growers might not worry about borer attack to their crop, so long as the percentage of attack did not exceed the extent of compensation. Mr. Khanna replied that the maximum compensation in the premonsoon shoots was of the order of 48 % and the minimum 26%.

Dr. H. S. Pruthi remarked that it was a very useful and important line of study and all the available data from different centres in India should be analysed and studied to see if the results were helpfully indicative.

PATHOLOGY SECTION

PATHOLOGY SECTION

Session—Wednesday, 1st February, 9-30 A.M.

Dr. B. L. Chona, *Chairman*

The Chairman delivered the following opening address.

Fellow Delegates, Ladies and Gentlemen,

I am thankful to the International Society of Sugarcane Technologists for the honour they have done me by asking me to preside over the deliberations of the Pathology Section of the present session (9th Congress). I am fully conscious of my limitations and the big responsibility and seek your kind cooperation and help to make the Proceedings of this Section a success—a Section which plays an important role in the welfare of Sugar Industry.

Sugarcane is one of the most important crops of India and the chief cash crop for the cultivator. The crop with an annual acreage of about 4 million and being the source of raw material for about 1.6 million tons of sugar production besides about 3.5 million tons of Gur (whole cane juice boiled down to solid state), is an important factor in the agricultural economy and the present day industrial set-up of the country—Sugar Industry being the second largest Industry of India next to the Textile Industry. India is now the largest single sugar producing country of the world, growing about one-third of the total world acreage under cane.

Like most crops, sugarcane is subject to serious disease hazards but it is possible to avert or greatly minimise such losses by suitable control measures in the evolving of which the Plant Pathologists have had and shall have an important role to play. I, therefore, propose to put before the House, very briefly, the sugarcane disease position in India at present, some important recent findings thereon and suggest some future lines of work for some of the important diseases. Of about three scores of diseases recorded on sugarcane from different parts of the world, 35 are known to occur in India. Fortunately most of them are of little economic importance. Otherwise sugarcane cultivation would have been perhaps an impossible task.

Virus Diseases : Of the various virus diseases *Scrch* and *Fiji* are not known to occur in India so far, the *Streak* was only once reported on a few solitary clumps of Uba variety imported from Africa years ago but did not spread to any other cane variety or even to other healthy clumps of Uba growing nearby owing, probably, to the absence of its insect vector in the country. The *Mosaic* is quite wide-spread and caused a great deal of apprehension when its occurrence in India was first discovered in 1921, owing to the fact that the mosaic disease was known to have caused considerable havoc in several cane-growing countries of the world. Survey tours were undertaken *poste haste* in 1928 only to find that the disease was prevalent in several parts of the country. A special scheme for the investigation of the disease was set up by the Govt. of India at the Indian

Agricultural Research Institute. The "Tonnage Experiments" carried out in the various cane tracts of the country with Co. 205, Co. 210, Co. 213, Co. 285 and Co. 313 revealed that even a 100 percent mosaic affected crop resulted in a reduction in yield of only about 10 percent and that the juice quality remained unimpaired. A 100 percent mosaic affected crop is not likely to be met with in nature as in most of the cane tracts of the country there is no active natural transmission of the disease. The losses through mosaic, therefore, were considered to be only slight. These findings laid aside the apprehension that was once felt by the Industry. But it has given a greatly relegated position to the study of mosaic, which, in my opinion, is not a very wise step, as the occurrence of a new strain more virulent than the 3 known to occur in the country at present, or some flare-up combination of the existing strains may cause a serious situation. Such a thing is known to have happened elsewhere and India can be no exception. A good watch should be kept for the introduction or occurrence of any new strains and, on principle, the seedlings at the Sugarcane Breeding Institute, Coimbatore, or any other Cane Breeding Station in the country, should be screened carefully for mosaic resistance prior to their selection as standard cane varieties. And that only mosaic resistant varieties should be encouraged for cultivation in such areas where active natural transmission exists. Furthermore, that the Coimbatore Station, which is the main fountain-head of cane varieties in the country, and has active natural transmission of the disease, should set its Live Herbarium and seed-multiplication nurseries at some nearby place which is free from natural transmission of the disease and should select seed cane material for distribution, particularly for sending abroad, from such nurseries only to avoid any chance of unintended dissemination of the disease.

Two new diseases, the *Grassy Shoot* and the *Twisted Top*, have come into prominence in recent years in the Bombay Deccan area, affecting Co. 419, the main cane variety of the entire tract. The grassy shoot disease greatly resembles the *Sclerophthora* disease and the *Dwarf* disease but is distinct from either. Preliminary investigations carried out at the Indian Agricultural Research Institute indicate that both these diseases are of virus origin and appear to be new diseases. Their incidence and spread, fortunately, seems to be low and slow but they should be carefully watched and studied and, as an emergency measure, the arrangements should now be envisaged for the replacement of Co. 419, in case it should become necessary.

The mysterious *Ratoon Stunting* has been spotted by Prof. Chilton at Golagokarnnath area in U. P. during the recent visit of the Delegates there. Immediate action is necessary to keep this serious disease under check and to carry out exhaustive surveys of all the cane areas in the country for Ratoon Stunting disease.

Fungal Diseases : Of all the fungal diseases, Red Rot is the most serious disease of sugarcane in India, particularly in the northern India Cane Tract, which grows about 80 percent of the total cane area in the country at present. Off and on the disease assumes an epidemic form. Severe outbreaks of the disease were reported in 1901 in the Godavari Delta (Madras), and in 1906 in Champaran and Muzaffarpore (Bihar). In 1922 there was a severe outbreak in Jammu (Kashmir). In 1932, at Pusa (Bihar) a severe infection occurred on Co. 210 suddenly after the complete absence of the disease for six years. Then again the disease disappeared from Pusa. In 1936, a severe but apparently local epidemic occurred at Intiathoke, near Gonda (Eastern U.P.) and in 1937 at Nagina (Western U. P.). In the Punjab at Ferozepore, the cultivation of the local Ponda variety (a thick, " noble " cane) had to be abandoned owing to the ravages of Red Rot. But the most unprecedented epidemic that the country has experienced is the one that occurred in the cane tracts of eastern U. P. and northern Bihar during 1938-40, resulting in complete devastation of thousands of cane fields of the predominant commercial variety, Co. 213, in the affected tracts and reducing the cane 'crush' of several sugar mills in the eastern U. P. to one-third of the normal amount in 1938-39 and one-half in 1939-40 owing to poor supplies of cane. A reduction of about 70,000 tons in sugar production of the country during 1938-39 was ascribed to the Red Rot epidemic.

Most of the earlier epidemics have been restricted to the thick, noble, cane varieties. The epidemic in the medium-thick cane, Co. 213, certainly represented a new phase in the history of Red Rot disease in India, as the thin indigenous canes and the new medium-thick Coimbatore canes had been looked upon as resistant to Red Rot. Sudden failure of the variety Co. 213 over wide areas in a tract where it had thrived and served the industry faithfully for nearly a decade was not without surprise and raised several issues of fundamental importance. An exact parallel is to be found in the Red Rot outbreak at Louisiana (U.S.A.) in P.O.J. 213 during 1930.

By 1941, although the epidemic was successfully controlled in northern Bihar and was showing a decline in eastern U.P., it had spread to other cane tracts in Bengal, Orissa, South Bihar, certain parts of central and western U.P. and eastern districts of the Punjab. Co. 213 was the variety chiefly affected at all the places.

The Red Rot epidemic flared up again in U.P. during 1946-47 affecting Co. 312 and during 1949-50 in northern Bihar affecting Co. 313 and Co. 453. Splashes of Red Rot were also observed in the eastern Punjab affecting Co. 312 and Co. 313 since the 1950-51 season.

Careful examination of thousands of canes in different localities in the epidemic areas clearly revealed that the 1938-40 Red Rot epidemic could not be ascribed to the use of diseased seed cane alone, as was the view of Butler who had first investigated the disease in India and claimed that the use of healthy setts completely controlled the disease. It had clearly revealed the presence of considerable secondary infection in the entire absence of any basal infection originating from the diseased setts. All this strongly indicated that some other factors were also operating. A reinvestigation of the disease was, therefore, undertaken by the Indian Agricultural Research Institute in order to determine the sources and modes of infection, spread and perpetuation, etc. of the disease and the control thereof.

Soil infection experiments have clearly proved that considerable Red Rot infection can occur through infected soil even if healthy setts are planted. We have to, therefore, change our conventional views of " Clean Setts and no Red Rot ". The farmer must have a " Clean field " besides " Clean seed ". The dried up Red Rot affected canes which are usually left over during the harvesting of the crop, must be removed from the field and destroyed so that they cannot act as a source of infection to the next cane crop in the adjoining fields. Fortunately, the survival of Red Rot infection in the soil is limited to only 5-6 months, but we should not feel unduly complacent over it as there is every possiblity of soil getting repeatedly infected owing to the existing cultural practices of cane cultivation ; thus resulting in the perpetual Red Rot infection in the soil.

Even a healthy crop, grown in a healthy field, from healthy seed, can become infected with Red Rot later in the season through irrigation water containing the spores of the Red Rot fungus, the infection taking place through the nodal regions of the cane near the ground level. The disease incidence brought about is greater if the infection with irrigation water takes place during the months of July or August where the crop is about 5-6 months old. The possibility for such an occurrence is great. In nature, the spores of the disease are produced in great abundance on leaf mid-rib infections of the disease by July or August and even slightly earlier on the shoots of Red Rot affected ratoon clumps or plant-cane clumps that may have become infected with Red Rot at the time of planting or soon after. During these very months, mass movements of water usually take place in nature, owing to heavy downpours of the monsoon rains, when water flows freely from one field to another and thus carry Red Rot inoculum from diseased fields to healthy ones.

Considerable Red Rot infection through the nodal regions of the cane was observed to occur in the epidemic affected areas in northern India. Several cane varieties were found to show this type of infection. Experimentally, out of the 96 cane varieties tested for this mode of infection through the nodal regions of the cane, 33 showed more than 25percent successful nodal infections of the inoculated canes. Highly susceptible varieties like Co. 213 showed 100 percent infection.

The possibility of such infection occurring in nature is great. The spores of the Red Rot fungus produced on the leaves get washed down with rain or excessive dew into the cavity between the cane stalk and the leaf-sheath and thus reach the nodes and cause infection, the infection taking place chiefly through the leaf-scar regions and the root primordia.

The young nodes, on the upper and middle portions of the cane, have been found to be comparativly more vulnerable to nodal infection than the older ones below. Great differences were also observed in different cane varieties in their susceptibility to this mode of infection. The varieties which possess a comparatively greater resistance to nodal infection are likely to remain free from disease even if growing amidst plenty of Red Rot inoculum around them. Such has been the actual experience in Red Rot epidemic affected tracts in U.P. and Bihar. Co. 313, Co. 356, Co. 421, etc. which have shown appreciable resistance to nodal infection, were observed to have remained almost free from Red Rot during 1938-40 epidemic even in the worst affected fields. Furthermore, it has also been shown that this power of nodal infection is not possessed by all the isolates of the Red Rot fungus. Evidently the predominance of only such isolates that possess the power of nodal infection could cause any appreciable secondary infection of the cane crop and bring about an epidemic.

Nodal infection, therefore, could be used as an important test to determine the pathogenic power of the prevailing Red Rot flora of any particular tract and the resistance of the cane varieties grown therein to predict the possibility of the outbreak of Red Rot epidemic.

Sett-infection experiments have amply confirmed Butler's view that the disease is carried over through diseased setts. Infection lesions were often observed passing from the diseased mother sett to the new shoots. Infection has also been found to be carried through ratooning diseased clumps, through cut ends of the setts and through the natural growth cracks occurring in the internodes of cane. General observations in the epidemic areas and soil infection experiments regarding association of borers with Red Rot have clearly shown that Borer holes play no important role in originating the disease or its subsequent spread under local conditions. These findings support Butler's view and are opposed to those of the workers in Hawaii, Louisiana, etc. Recent reports from Mauritius also show that the large proportion of attack of Red Rot could not be correlated with Borer injury.

A light coloured, highly sporing, type of the Red Rot fungus predominated in the isolations made from Red Rot affected canes from epidemic areas of U.P. and Bihar, whereas all the previous isolates in our collection prior to 1938 are of a dark type with sparse sporulation. The new, light type isolate is much more virulent than the old dark type. By the virtue of its profuse production of spores it is naturally well suited for quick and widespread dissemination.

In this change of Red Rot flora in the epidemic areas resulting in the predominance of a highly sporing, highly virulent strain, combined with secondary nodal infection was found an explanation of the failure of this once important commercial cane variety (Co. 213).

This clearly points to the existence of different strains of the Red Rot fungus with varying power of pathogenecity. A large number of isolates were tested for the study of the physiologic forms of the Red Rot fungus. A great deal of difference in the virulence of various isolates was observed, but there do not appear to exist any highly specialised physiologic forms like those of the wheat rust fungus, with definite specificity between an isolate and a particular cane variety or set of varieties. Various isolates fall into two groups mainly from general cultural appearance : the light, freely sporing and the dark, sparsely sporing types. Generally speaking, the light type are more virulent than the dark type ; but there are a few exceptions. Some light type isolates are only weakly parasitic. It might, however, be mentioned that the isolate obtained from the 1946-49 Red Rot epidemic areas of U.P. seems to be more pathogenic on Co. 312 and Co. 313 than the isolate of 1938-40 epidemic that had chiefly affected Co. 213 crop. Recent reports from Bihar also show as if a new strain, particularly virulent on Co. 313 and Co. 453, has been isolated. Isolations made from the recently Red Rot affected areas of eastern Punjab have also yielded a very virulent type of the Red Rot fungus. At present about 8 distinct strains of the fungus are reported to exist in India. This obviously is the most important feature of the Red Rot epidemic, as the development and predominance of a new more virulent strain may result in the failure of any of our existing commercial varieties and may thus upset the varietal set up of a tract which takes quite a few years to build up. This point needs careful further investigation in order to determine as to how the new virulent strains arise in nature as also the possibility of preventing the multiplication of *C. falcatum* inoculum on the leaves and stopping nodal infection. A search for suitable systemic fungicide is clearly indicated. Recently the occurrence of the perfect stage of the Red Rot organism in India has been reported. Its role in the development of the new strains needs investigation.

Red Rot leaf infections are found to occur, in plenty, even in areas where there is no appreciable Red Rot injury to the crop, e.g. Shahjahanpur, Delhi, Karnal, etc. Several isolations made from the diseased leaves from these localities yielded dark type, weakly parasitic Red Rot strain. The absence of Red Rot infection in the cane crop in these areas could, reasonably, be ascribed to this fact.

Cultivation of resistant varieties is the easiest and the cheapest way of controlling any disease. It was realised very early in the investigations of Red Rot disease in India that the *desi* thin indigenous canes (*S. barberi*) were far less susceptible to Red Rot than the thick canes. In our observations of the numerous fields, under the indigenous cane varieties in the epidemic tracts, we have not come across any Red Rot attack on these varieties, except a few solitary cases in one locality during the third year of epidemic. In many cases the *desi* was being grown as border to the main field of Co. 213 and it was observed that while the Co. 213 crop was badly affected with Red Rot, the disease could not be found in the border rows of the *desi*. Unfortunately, the tonnage and sucrose recovery of such varieties is too low to meet the demands of the Industry.

The testing of a large number of important and promising commercial cane varieties each year has been the regular feature of our work on sugarcane diseases at the Indian Agricultural Research Institute since 1936, as also at the Main Regional Sugarcane Research Stations as they got their Mycological units, with a view to enable the selection and recommendation of suitable cane varieties for cultivation. From 1945 onward the varietal resistance tests were extended to important parent cane varieties and other *Saccharum* spp. to enable the selection of resistant cane varieties for cane breeding work.

By now about 500 cane varieties have been tested. A vast majority have reacted as moderately resistant, 20 as resistant and 70 as highly susceptible. The varieties Co. 441, 532, 547, 548, 549 and Co. K. 34 have reacted as highly resistant and may be found helpful in combating the disease.

The results of the Red Rot varietal resistance tests extending over several years provided sufficient information regarding the resistance or susceptibility of certain cane varieties to Red Rot. This basic information made it possible to attempt the breeding of cane varieties resistant to Red Rot. The work along these lines has been started as a collaborative project between the Division of Mycology and Plant Pathology of the Indian Agricultural Research Institute, New Delhi and the Sugarcane Breeding Institute, Coimbatore. Certain controlled crosses were effected with Resistant, Moderately Resistant and Susceptible varieties and the progenies assessed for their Red Rot resistance. These preliminary studies on the inheritance of Red Rot resistance have shown an indiscriminate distribution of resistance or susceptibility among all the Progenies. Even a Susceptible x Susceptible cross has given some Resistant seedlings and *vice versa*. Similar results were obtained with the varieties derived from Resistant or Susceptible Pistil Parent. Thus obviously indicating that the only way to evolve Red Rot resistant varieties is the careful screening of the seedlings and the cane varieties and selecting only those which show fair degree of resistance. It is of utmost importance that if the hazards of Red Rot to the sugar industry are to be averted satisfactorily, a great care must be exercised in recommending and releasing sugarcane varieties and encouraging cultivation of those that are fairly resistant to Red Rot. This is the only way to prevent serious annual losses or the periodic outbreak of epidemics.

In view of the fact that the Red Rot, under local conditions in India, is a disease of the growing crop, and that the resistance of the growing canes is quite different from that of the cut canes, it is essential that to get a true picture of the behaviour of cane varieties to Red Rot, inoculations should be made on growing canes in a number large enough to counteract inevitable variability of results under field conditions and the experiment should be allowed to run for 5-6 months to allow full scope for the development of the disease in the inoculated canes. A standard method—the Plug Method—has been evolved and is being used throughout the country for Red Rot resistance tests.

There is, however, one draw back in this method of testing : the cane rind is wounded and the inoculum is placed straightaway in the interior of the cane, thus doing away with the resistance that cane plant might have offered to the entry of the fungus into the cane. The fungus may progress rapidly within the cane once it reaches the interior soft cane tissue but may not be able to effect the entry easily. Experiments were, therefore, elaborated from 1942-43 onwards to test the relative resistance of a large number of cane varieties to Red Rot infection through soil, irrigation water and the nodal regions of the cane. These three methods for testing varietal resistance against Red Rot are superior to the Plug Method in that they do not involve any deliberate wounding of the cane plant for inoculation and the mode of infection is more natural. These methods may be reliably employed for testing field resistance of cane varieties to Red Rod, particularly the nodal infection test. Furthermore, these methods are less laborious. But to have an idea of true inherent resistance of a cane variety the Plug Method is the only sure test.

The selection of the *C. falcatum* isolate to be used in these varietal tests is obviously of utmost importance. *C. falcatum* isolates from various cane varieties and localities should be studied for their virulence and only the most virulent one should be used for the varietal resistance test for the first screening and the selected resistant varieties should be then tested against a few other virulent isolates from different epidemic affected cane tracts.

One more point, however, has to be kept in mind, i.e. the proper maintenance of the selected isolates in a pure, virulent form, as some of the isolates have been found to mutate in the culture and lose virulence. It has been found that mutation in *C. falcatum* occurs more frequently on a rich medium like Richards' and in older cultures. Periodic single-sporing and frequent subculturing have proved very useful for the purpose.

As at present no cane variety, possessing desirable commercial requisites, is absolutely immune to Red Rot, adequate care to keep the seed stocks free from the gradual accumulation of the disease would be necessary even if resistant varieties are grown. This can be easily achieved by maintaining seed plots and following a few simple practical cultural practices. The seed plots should be preferably located in areas of low disease incidence.

A nucleus of the Seed-Nurseries Scheme initiated by the Sugarcane Research Station, Pusa, is now being extensively followed in Bihar and other important sugarcane growing tracts in the country to assure the supply of certified disease-free healthy seed to every cane-grower.

Smut : Next to Red Rot, Smut is the most important disease of sugarcane in India. The disease is characterised by the production of a long, black whiplike structure from the apex of the affected cane ; sprouting of the lateral buds into shoots, which soon develop smut whips ; production of tall, thin, spindly canes and excessive tillering.

The disease is usually more prevalent in hot dry arid regions and on the thin, indigenous cane varieties (*S. barberi*) ; but may accumulate to serious proportions in any region, if its irradication in initial stages is neglected.

Smut spores from whips are blown about by wind and fall on the canes nearby and infect their " eye " buds. The infected " eyes " may sprout into smutted whips during the same season ; or the mycelium within these "eyes" may lie dormant until the setts are planted, when smutted plants are produced early in the season. The young " eyes " are more vulnerable to infection. The spores that fall on the ground are carried about the field in irrigation water or rain water during the rainy weather and come into contact with the "eyes" on the basal portion of the cane and infect them. The survival of sugarcane smut spores in the soil for any length of time does not seem probable as these spores, unlike other smut spores, do not seem to have a long resting period and lose their viability in 3-4 month's time.

Smutted canes with main or lateral shoot infection and even healthy canes in the smutted clumps harbour smut-infection and on planting perpetuate the disease. Even healthy clumps growing in the vicinity of smutted clumps are found to harbour slight latent smut infection. Ratooning of smutted clumps is another source of perpetuating and spreading the disease. *S. spontaneum*, a wild grass, which is abundant and wide-spread all over the country, has been found to be infected with sugarcane smut, thus indicating its role as collateral host of sugarcane smut fungus and the desirability of roguing out of *S. spontaneum* plants from the neighbourhood of cane fields is essential.

Physiologic Forms studies show little indication of physiologic specificity of the sugarcane smut fungus, sugarcane smut from these indigenous canes, thick *S. officinarum* type canes and the medium thick Co. canes freely infected all the three types of the cane varieties.

Some unusual smut infections of the inflorescence, stem and leaf have been observed and found to be caused by *Ustilago scitaminea* Syd.

Smut is capable of causing considerable loss to the cane crop if the infection sets in early in the season. The Assessment of Damage experiments with sugarcane smut during 1949-50 at Delhi showed a reduction in yield (millable shoots) of 29 percent in case of Co. 312 and 23 percent in the case of Co. 313. In the ratoon crop of the smutted clumps the losses were found to be much higher—upto about 70 percent.

Varietal Resistance tests carried over a number of years have clearly shown great differences in relative resistance of various cane varieties. Out of about 600 cane varieties tested so far, only 20 have reacted as highly resistant. *S. barberi* and *S. spontaneum* (Coimbatore) which have been chiefly used in the crossing work at the Coimbatore Cane Breeding Station, have been found to be highly susceptible to Smut, which may be responsible for the high susceptibility of most of the Co. cane varieties. *S. spontaneum* (Java) and *Sclerostachya* proved much more resistant than *S. spontaneum* (Coimbatore). A large number of *S. spontaneum* variants and other wild *Saccharum* spp. in the collection of Sugarcane Breeding Institute, Coimbatore, are being screened for smut resistance and a great deal of variation about in resistance has been observed in different variants.

It has been found that systematic roguing and seed selection for three successive seasons effectively controls the smut disease ; and that even a susceptible variety could be successfully cultivated and could be kept free of smut infection.

A severe epidemic of smut was observed during the 1942-43 season in Bihar, affecting about 66 percent of the total cane area, and in Hospet area in Madras (now Andhra) during 1947. Anti-Smut Campaigns organised along the lines of Systematic roguing and selection of seed cane material gave very encouraging results at both the places. These operations may not be economical in the tracts with high labour wage and in such areas the only practicable control would be the cultivation of resistant varieties. The smut incidence is reported to have increased considerably in Co. 419 in certain cane tracts of Madras State.

Fungicidal treatment of seed cuttings has been found to be effective only against external infection but proved of little avail for internal infection, which is the main type of infection in nature. Hot water treatment of setts (at 55-60°C for 10 minutes), however, effectively controlled smut infection but greatly impaired the germination and is, therefore, of no practical value.

Wilt : The Wilt disease of sugarcane, caused by *Cephalosporium sacchari* Butler, may occur independently or in association with Red Rot, severe attack of Root Borers or Shoot Borers. The disease is reported to be of considerable importance in certain areas in eastern U.P. near Gorakhpur and Saran area of Bihar. The disease is generally observed soon after the monsoons and is more pronounced in the light soils. The losses are reported to be of the order of 20-25 percent of field tonnage and a serious drop in sugar recovery in the affected areas in Bihar.

A large number of experiments on soil infection and sett infection failed to produce typical Wilt infection under Delhi and Karnal conditions. The failure of infection may be due to the weakly parasitic nature of *C. sacchari* or the absence of proper environmental conditions for the development of the disease. Recently, the Sugarcane Research Station, Pusa, have reported a method of obtaining successful infection under controlled conditions which would be of great help in screening the varieties for wilt resistance.

Fusarium moniliforme is reported to aggravate the disease. The exact role played by this organism requires careful investigation as also the conditions under which *C. sacchari* becomes actively parasitic.

The identity of *C. sacchari* is questioned. It is being claimed as *F. moniliforme* var. *Subglutinans*, whose perfect stage is *Giberella fujikuroi*, by the Central Bureau of Fungal Cultures, Baarn, Holland.

Top Rot : This disease is similar to " Pokkah Boeng " of Java caused by *Fusarium moniliforme* Scheld. The disease though reported to be very serious in Java is not at all serious under northern India conditions. It is more prevalent from Gorakhpur onwards towards East. The disease is almost omnipresent during the monsoons, affecting almost all the cane varieties to a lesser or greater extent. The affected plants are, however, found to recover completely later in the season. The disease as studied in Surkha Saharanpuri (a thick, noble cane variety) at Karnal and Co. 312, Co. 313, Co. 285 and Co. 223 at Delhi revealed no loss of cane yield or impairment of juice quality in Top Rot affected clumps as compared to the adjoining healthy ones indicating thereby that the disease does practically no damage under the soil and climatic conditions as obtained at Delhi or Karnal (Punjab). It may be, however, mentioned that in the eastern parts of the northern India, where the conditions are favourable for the infection and the spread of the disease for a longer period, the disease may cause more damage. A severe type of infection of Top Rot, producing ladder-like necrotic lesions on the rind of the cane at the point of infection, has been observed at Nellikuppam (Madras). Though the normal growth is resumed later, the point of infection remains a weak spot and often the cane stalk breaks off at this point during the heavy winds which are quite common in that area and thus cause a considerable economic loss.

The disease is also found on sorghum and maize and it would be, therefore, desirable to study the inter-relationship of the three isolates.

Rust : This disease which was known to be only of rare occurrence on sugarcane in India suddenly became prominent in certain cane tract of Bombay Deccan during 1949-50 season affecting Co. 475. Subsequently Co. 876 and Co. 928 have been reported to be affected with Rust at Nellikuppam (Madras). Co. 475 and Co. 876 have been found to be affected at Hyderabad Deccan also. However, Co. 419, the main cane variety of these tracts, has remained free from Rust infection so far, though growing in close proximity of the affected varieties. This disease does not seem to be doing any serious damage to the crop as the duration of the disease is short and the attack is usually confined to the older leaves. But considering the serious nature of Rust diseases, the Bombay State has, on the advice of the Indian Central Sugarcane Committee, very wisely withdrawn Co. 475 from general cultivation in spite of its excellent agronomic performance.

From taxonomic point of view, these Rust collections have been of special interest as they showed the presence of the Teleuto-stage of the Rust (*Puccinia kuehnii*) on sugarcane, which happens to be the first world record.

Rust infection of several wild *Saccharum* spp. is reported from India but none of these has yet been found to infect *S. officinarum* indicating thereby the possible existence of physiologic races of the Rust.

Leaf Spot Diseases : Generally speaking, the cane crop in India is singularly free from any serious leaf spot disease as compared to some other cane growing countries. However, *Helminthosporium* Eye spot, and *Cereospora* leaf spots are commonly encountered. The yellow leaf spot (*C. kopkei*), previously reported from Assam only, has been found to affect Co. 419 along the Malabar coast in recent years and is becoming quite prevalent in Nellikuppam area also.

Seedling Diseases : *Pythium graminicolum* and *Helminthos porium halodes* have been found to cause damping off of seedlings in the pans. Spraying the soil with 0.05 percent mercuric chloride solution and burning trash on the surface of the soil in pans prior to showing the fluff greatly reduced the disease. Reduction in seed-rate from 3 grams to 1 gram per pan and the use of newly baked pans also gave an effective control of the disease.

Bacterial Diseases : Of the various bacterial diseases, only Red Stripe and Stinking Rot are known to occur in India of which the former is more important. Red Stripe is a premonsoon hot weather disease which is prevalent during the months of May and June and passes off with the onset of monsoon rains. The disease incidence varies greatly from year to year and periodically it apears in an epidemic form. In 1938-39 a severe outbreak of the disease occurred at the Sugarcane Research Station, Punjab near Lyallpur and in 1939-40 at Kalai Farm near Aligarh in U.P. At both the places the variety affected was Co. 312. Severe outbreaks of the disease have also been observed at Dacca and Sepaya (Bihar) and has recently been also reported from Phalton Sugar Mills area in Bombay

Deccan. The disease seems to cause little economic loss, as the affected plants recover almost completely from the disease later in the season.

Phanerogamic Parasites : Two species of *Striga* (*S. lutea* and *S. euphrasioides*) are known to attack sugarcane in India as Root parasites. Striga trouble is reported to be serious from Bhopal, Hyderabad and certain parts of Bihar and Punjab. These attack the host at any stage of growth killing it outright in cases of severe infection of young crop. Light soils show greater concentration of the parasite.

The cane striga can attack paddy, paspalam, maize and sorghum but not *Pennisetum typhoides*. It can also parasitise *S. spontaneum*. These secondary hosts must be avoided in any rotational scheme intended to starve out *Striga* from infected soil.

Successful control of Striga with Methoxone (@26 lbs. per acre) and Agraxon has been reported from Sugarcane Research Station, Pusa (Bihar) and Coimbatore, respectively.

In the absence of the authors the following paper was presented by Mr. D. R. Strong.

Paper

TESTING SUGAR CANE VARIETIES AGAINST FIJI DISEASE AND DOWNY MILDEW IN FIJI

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Many cane sugar producing countries of the world occupy isolated positions in relation to others. This unique geographic relationship, combined with plant quarantine regulations, has, in the past, contributed a barrier against the spread of serious diseases and pests from one country to another. Not many years ago, sea travel and transportation and the time required in going from one port to another were often responsible for the failure of a new pest or disease to reach and become established in a different country. With the advent of air travel and transportation, the barriers that once existed have to a large degree been broken down and each country is much more vulnerable to invasion by new diseases and pests than during the days of surface travel and transport. With faster and more frequent air travel it becomes necessary to rely more than ever upon rigid quarantine measures to prevent the invasion of a new disease.

The fact that living insects are recovered in commercial planes arriving from distant airports is a serious problem in many countries. To cite a specific instance, reference is made to where a few to large numbers of living sugarcane leafhoppers, *Perkinsiella vitiensis*, have on eleven different occasions been recovered during the past three years on commercial planes arriving at the International Airport in Honolulu from Nandi, Fiji. This information was obtained from the Plant Quarantine Branch, Agricultural Research Service, U.S.D.A. in Honolulu, through Dr. C.E. Pemberton, Retired Entomologist, Experiment Station, H. S. P. A. Dr. Pemberton also states, " The hoppers are attracted to lights and unavoidably enterthe planes whenever hopper flights are occurring. Leafhopper flights are not a nightly occurrence, but seem to be influenced by weather conditions. In Hawaii it has been observed that leafhopper flights occur most frequently on quiet nights when air currents are at a minimum."

When weather permits, several of the commercial airlines overfly Canton and reach Honolulu from Nandi, Fiji, a distance of 3100 miles, in approximately 11 hours. Leafhoppers carrying the Fiji disease virus and " boarding " a plane at Nandi could conceivably be feeding on grasses or cane some 12 hours later.

It must also be pointed out that new pests or diseases could reach Hawaii from the Philippines by plane or by cane cuttings brought to Hawaii as souvenirs by persons unfamiliar with plant quarantine regulations. Other countries, are, no doubt, exposed to invasion of new pests and diseases by conditions similar to those discussed in relation to Hawaii.

In reviewing the major sugarcane diseases of the world and their control, it is clear that the most satisfactory control has resulted from the use of resistant varieties. Some of the serious diseases which have been effectively controlled through breeding commercial varieties resistant to them are sereh, mosaic, leaf scald, Fiji disease, downy mildew, eye spot, *Pythium* root rot and gumming.

Should a new disease gain entrance into a country, information on the resistance of local varieties must be available before an efficacious control of the disease can be initiated. If this information is not available, steps should be taken immediately to obtain it.

Realizing the vulnerability of the Hawaiian sugar industry to invasion by new diseases as the result of increased air travel, and, realizing also the necessity of knowing the resistance of local varieties to new diseases, arrangements were made in 1946 to test Hawaiian grown varieties against Fiji disease in Samoa (American). This testing programme continued until February 1952. During 1951 a co-operative project was started, between the Hawaiian Sugar Planters' Association and the Colonial Sugar Refining Co., Ltd., to test Hawaiian grown canes against downy mildew and Fiji disease at Lautoka, Fiji. A number of the commercial and promising new varieties developed in Fiji and Australia by the C. S. R. Co. Ltd., as well as commercial and breeding canes imported from other countries, are included in the disease trials. The results of the disease trials to date have been most satisfactory.

The following part of this paper deals briefly with the history, cause, economic importance and control of each disease and the methods employed in the trials and for evaluating the results therefrom for determining varietal resistance.

FIJI DISEASE

History :- It is not known when Fiji disease of sugarcane (*Saccharum* virus 2) was introduced to the British Crown Colony of Fiji (from which the disease takes its name) but by 1886, it was widespread in the Rewa River district and by 1906 had become so severe that the industry was threatened with extinction in certain districts.

By the efforts of D. S. North (at that time Plant Pathologist to the Colonial Sugar Refining Co., Ltd.), who devised methods for its control losses were reduced to small proportions. The names of other scientific investigators who are remembered as adding to knowledge of the disease at this period, were fittingly enough, Hawaiian. F. Muir (14) from the Experiment Station of the H.S.P.A. paid a visit to Fiji and took back records and photographs to Hawaii, and, in 1910-11, H. L. Lyon (10) devoted himself to a histological study of the galls and other aspects of the disease.

The disease was present in Australia in 1889 in the Clarence River district of New South Wales and by 1927 had been found as far north as Bundaberg in Queensland (2). Minor epidemics have occurred from time to time in both states. It was also reported as having occurred in the Philippines as early as 1916 (22), the inference being that it had been introduced from Australia or Fiji from whence several cane importations had been made. It was reported as occurring in New Guinea in 1914 by Carne (17) and found in a collection sent from New Guinea to Australia in 1928 (18). Hughes (3) gives further records of the disease found by expeditions to New Guinea or New Britain or intercepted in material sent from these places from 1937 to 1951.

Fiji disease was also intercepted in plants from the Philippines by Javanese authorities in 1930 but presumably did not become established (6). The disease is known to occur in the following countries ; Australia, Fiji, Madagascar, New Britain, New Caledonia, New Guinea, Philippines, Samoa and Solomon Islands. The Pacific islands are well represented but the disease has found its way as far afield as Madagascar in recent times (4).

Cause and Symptoms. The cause of Fiji disease was not discovered until many years after methods for its control had been evolved. In 1932 Ocfemia (20) demonstrated that the disease was transmitted in the Philippines by the leafhopper *Perkinsiella vastatrix* Bred. In 1933 Mungomery and Bell (15) published conclusive evidence that the disease was probably a virus and was transmitted in Australia by a closely related leafhopper, *P. saccharicida* Kirk. This was confirmed by North and Baber (19) in 1935. In Fiji, the vector has not been identified but the only species of *Perkinsiella* found in the Colony is *P. vitiensis* Kirk, and, by analogy, seems the most likely insect vector. (*Note* :—a single individual of *P. saccharicida* was recorded many years ago in Fiji but as the species has not been recovered since, the record was apparently in error).

Mungomery and Bell (15), North and Baber (19) and Ocfemia (21) established that the hoppers must feed on diseased cane in the nymphal stage to become infective and remain infective throughout adulthood. So far as is known, no investigations have been carried out to determine how long the nymphs must feed on diseased material in order to acquire the virus and whether there is any incubation period in the insect itself. Transmission studies of North and Baber (19) showed that nymphs and adults, once infected, may transmit the disease with equal facility. Later, Baber and Robinson (1) presented evidence that nymphs might be more efficient vectors due to their ability to reach phloem tissue more readily when feeding, and suggested that former experiments may have favoured adults by extending the feeding period on infected plants. Experiments of North and Baber (19) showed that there is an optimum age for infecting plants (about 2 months from planting) and supported Mungomery and Bell's findings that rank growing crops on rich land in wet summer seasons are most favourable for infection.

The symptoms of Fiji disease have been well described by Mungomery and Bell (15) and so will only be briefly summarized here. Single stalks of cane infected with the disease have a characteristically malformed top (Fig. 1). The

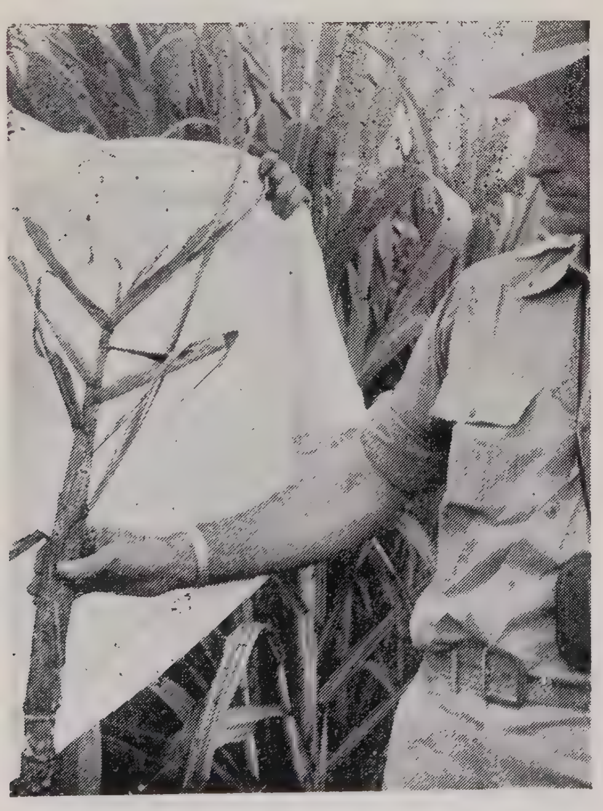

Fig. 1. The variety Galba affected with Fiji disease at Nausori, Fiji (1947). The shortening of the cane leaves and the depressed growth of the stalk are typical symptoms of the disease. C.A. Wismer holds specimen in the picture.

leaves are presented in fan shaped fashion, the youngest of which are distorted, much shortened and somewhat scorched in appearance. The effect of the whole has been aptly described as such as "might be expected if some animal had bitten off the upper portion of the leaves before they had unfolded" (15). Small swellings (galls) (Fig. 2) are found on the underside of the leaves of infected plants and serve to identify the disease positively (Fig. 3). These may vary in colour from shiny white to practically the same colour as the leaf. One or more such stalks may be found with or without healthy stalks in the same cluster (Fig. 4). They

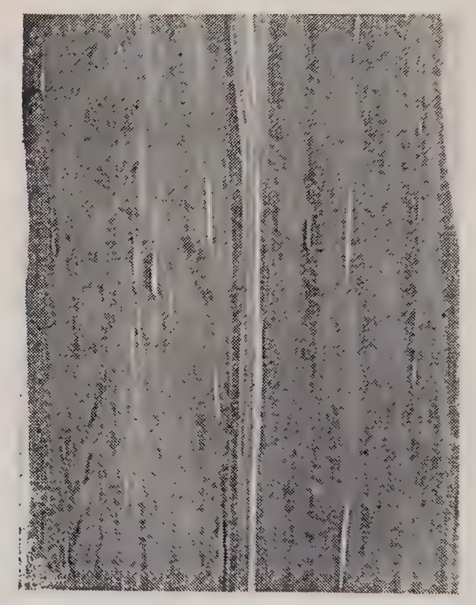

Fig. 2. Galls of Fiji disease on the lower leaf surface of Yellow Caledonia.

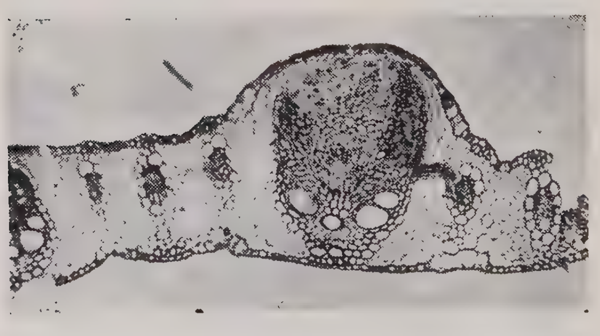

Fig. 3. Cross section through a leaf gall of Fiji disease. The gall is produced on the lower leaf surface by cell proliferation and by disorganization of the phloem tissue. After Kunkel.

are stunted in varying degrees in comparison with apparently healthy stalks and sometimes possess sideshoots.

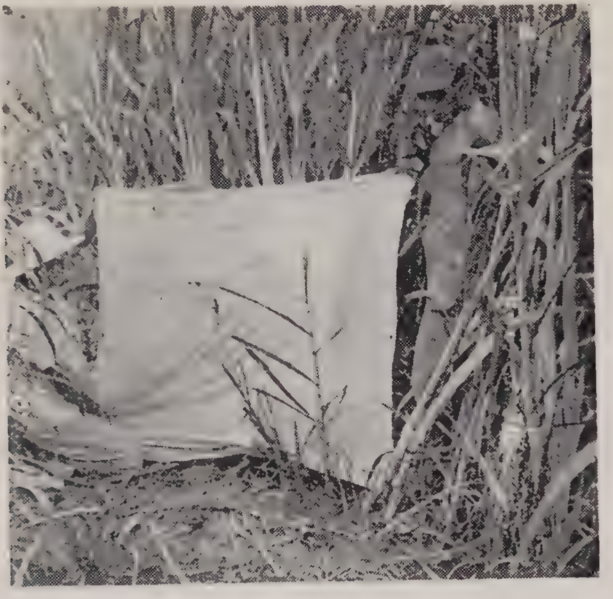

Fig. 4. The variety 37-1933, age 7 months, affected with Fiji disease in Samoa. Note severe stunting caused by the disease in contrast with healthy cane.

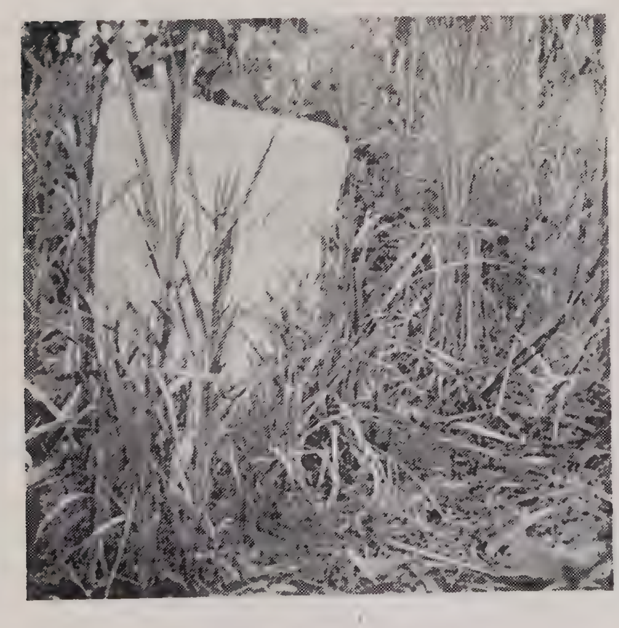

Fig. 5. Plot of cane infected with Fiji disease in foreground with healthy cane in the background. Note depressed growth of diseased cane.

On ratooning diseased stools or planting diseased setts, the resulting plant is usually extremely stunted and resembles a tussock of grass about 1-2 feet high (Fig. 5).

During the testing of many different varieties, opportunities are offered for observing instances of symptoms varying from the classical description. Tolerant varieties, have been noted in which the malformations described above have been reduced to a minimum in secondarily infected plants. Often the only symptoms in the latter type of plant are a few minute galls scarcely visible but positively identifiable. Freak galls of up to 3 inches long have also been found at times (Fig. 2). Old leaves of a very dark green colour are found on most infected varieties but cases have been recorded where infected plants are wholly chlorotic with a colouring resembling extreme nitrogen deficiency in cane.

Economic Importance and Control:- Fiji disease has caused serious losses on more than one occasion in N.S.W. and Fiji and to a lesser extent in southern Queensland.

In 1907-08, thousands of acres of cane were destroyed in Fiji, and the industry in the Nandi district was threatened with extinction. In 1920 the disease reached epiphytotic proportions on the cane lands of northern N.S.W. In 1929, floods on the Rewa River in Fiji were followed by a large increase in Fiji disease and in 1931 approximately 9,000 tons of cane (10% of the total crop) were destroyed. The susceptible Malabar (Yellow Caledonia) constituted the major proportion of the crop. The variety of P.O.J. 2878, and other near relatives of Kassoer derivation, were introduced into Australia and Fiji in the 1930's. This proved fortunate for controlling gumming disease in Australia but the blood line proved so susceptible to Fiji disease that an alarming increase of the disease occurred both here and in Fiji. These valuable varieties had to be replaced in N.S.W. and Fiji after control by other means had proved unsuccessful. Reports from Madagascar indicate that the present outbreak is a severe one.

It is difficult to assess the actual damage in economic terms of these epidemics. Besides the direct losses in tons of cane destroyed or in depleted yields, there are numerous costs of an indirect nature which are difficult to evaluate, viz. those incurred in attempting to eradicate or control the disease by roguing or by the substitution of inferior but resistant varieties. In Fiji, for instance, it has been necessary to maintain an annual roguing campaign against the disease for many years involving the payment of large numbers of workers for this purpose.

In Australia, Fiji disease has been reduced to negligible proportions. Its scarcity in some districts of N.S.W. and Queensland in later years amounts almost to elimination. This has been brought about by a combination of measures including the substitution of resistant varieties, the use of disease free seed cane and sustained roguing of infected plants. When the relative merits of the various methods of control are examined, it cannot be denied that the most effective is the use of resistant varieties.

Evidence of the remarkable reduction which can be achieved by the use of resistant varieties supplemented by seed selection and roguing is given by

King (15) in regard to southern Queensland. This is supported by the experience of the Colonial Sugar Refining Co.'s three mills in northern N.S.W. In the latter area, resistant varieties replaced the susceptible P.O.J. canes over a period of years and losses from the disease decreased from 2.0% of the crop harvested in 1944 to negligible amounts in 1953. At two mill centres no disease was found in the usual survey for that year.

The degree of control in Fiji has not reduced the incidence of Fiji disease to such small proportions as in Australia. This is due partly to the growing of varieties with low resistance in certain areas, partly to the inefficiency of labour available for roguing, and in some measure to the favourable biological conditions prevailing for the disease. The controllable factors are at present receiving attention and it is hoped to reduce the incidence of the disease still further. Variety replacement in Fiji is complicated by the presence of another serious disease, Downy Mildew, and by a number of ecological requirements. One of the most important aims of a new seedling raising programme in Fiji is to produce commercial varieties proven resistant to these diseases in controlled disease resistance tests.

In Fiji, the leafhopper vector of Fiji disease, *P. vitiensis* Kirk., flourishes abundantly. On sugarcane, populations of this insect reach enormous proportions in the peak period of March/April (the wet summer season). This population gradually dwindles with the advent of the drier season and with the rise of parasites and predators. By September/October, there is a noticeable drop in numbers but this does not appear so marked as is the case with *P. saccharicida* in the winter in the semi-tropical areas of Australia. In Fiji, the equivalent period is distinguished by a fluctuating population depending on locality and the varying severity of the dry season. Some areas appear capable of harbouring appreciable numbers of the insect the year round. In these, only a prolonged drought has the effect of drastically reducing populations.

Similar parasites and predators of the leafhopper, which occur elsewhere, also abound in Fiji but likewise exercise a very belated control over the increase in population of the hopper. Of these, *Cyrtorhinus mundulus* Bred (an egg parasite) is considered an effective controller of the kindred *P. saccharicida* in Hawaii and is also probably the most important in Fiji. Observations in Fiji trials show that increase in the numbers of this insect lags behind that of *P. vitiensis* to such an extent that it may have very little effect in reducing the spread of Fiji disease.

At the commencement of the wet season, infected cane plants in existing plant or ratoon crops (6-8 months age) act as a reservoir of the virus. Together with residual infected hoppers and primarily infected current season plants, they are the source of a further spread of disease in the ensuing months so favourable to leaf hopper multiplication.

The planting season in Fiji extends from December to June (summer-autumn months), the bulk of planting being completed in the early autumn at the latter end of the wet season. The highest concentration of infected leaf-hoppers is thus reached at a period when newly planted cane is at its most succulent and susceptible stage of growth.

A combination of factors favourable for infection and transmission of Fiji disease exists in Fiji and increases the difficulties of control of the disease. Consequently, when assessing the potential of new varieties, it has been found necessary to adopt a somewhat higher criterion of resistance than would suffice under Australian conditions.

DOWNY MILDEW DISEASE

History.

Proof is still necessary that the casual organism of Downy Mildew (*Sclerospora sacchari*, T. Miy) originated in New Guinea, although all evidence points in this direction.

The first record of Downy Mildew in Australia, although rumoured to be present earlier, was an outbreak in the Herbert River district in North Queensland which was investigated by D.S. North in 1910 (16). North diagnosed it as an infectious disease caused by a member of the Peronosporaceae and referred to it as " leaf stripe ". Miyake's investigations on this fungus were not at that time available to North.

About the same time, the disease was detected at Rarawai Mill in Fiji where it was differentiated from a similar disease on indigenous wild canes mainly in *Miscanthus japonicus* and occasionally Veico (*Erianthus maximus* Brong). The latter disease, on which no conidial down is formed, either on sugarcane or *Erianthus*, was previously well known to North and called " leaf splitting " (later *Sclerospora northii* West).

Downy Mildew was observed in Formosa in 1909 on varieties introduced from Java and Queensland, the latter country finally being held responsible for its origin. The disease was investigated by T. Miyake and the causal fungus named *S. sacchari* T. Miy. (13). North further investigated the disease in the period 1911-15 and corroborated the findings of Miyake (16).

Lee and Medalla (7) recorded the disease in the Philippine Islands in 1920, brought thither in a shipment of cuttings from Formosa. A brief outbreak of Downy Mildew was promptly eliminated in India in 1930 (12), but the identity of the fungus was later questioned by Subramaniam (23). Lennox, in an expedition to New Guinea in 1937 recorded Downy Mildew for the first time (9), but it was found abundantly by the Bureau of Sugar Experiment Station's expedition in many areas in 1951 (Hughes 3). Hughes suggests that there may be a number of species allied to *S. sacchari* occurring in New Guinea.

Downy Mildew now occurs in Australia, Fiji, Formosa, India, Japan, New Guinea, Philippines and Siam. From this it will be seen that Downy Mildew is of great importance to the Pacific region.

Causal Organism

The causal fungus is an obligate parasite belonging to the genus *Sclerospora*. Descriptions and illustrations of each stage—conidiophore, conidia and oospore—have been published by Miyake (13).

The characteristic mycelium and haustoria of the fungus may be demonstrated in any infected part of the host. The oval conidia are produced nocturnally from midnight onwards from tree-like conidiophores which are wedge-shaped and narrow at the base. One or two conidiophores arise from each stomate on the undersurface of the leaf on the discoloured areas and bear about 20 conidia.

The conidia germinate by producing germ tubes about dawn in films of moisture. Miyake did not induce germination on artificial media but North (16) evolved a method of inducing conidiophores with production and germination of conidia by surface sterilizing small portions of diseased cane leaves and growing them on oat agar. The conidia germinated but no further development took place on artificial media.

It was established by Miyake and North that the buds on cane stalks are readily infected. Both these investigators were unsuccessful in inoculating plants through the leaves or spindles of young cane, although infections did take place as red spots and limited leaf streaks were noted after 3 days. Miyake demonstrated the presence of mycelium and haustoria in such infected tissue but the disease did not develop further or reproduce conidia on the " infected area."

In the field, early symptoms of infection are noticeable at the base of unfolding leaves pointing to the fungus having proceeded upwards. However, the ease with which very young shoots and seedlings become infected leaves no doubt in the mind of the writer that the spindle itself (or the youngest portion of the leaves in this region) is susceptible to infection at this stage of growth. This view also seems to be supported by Leece (8).

The oospores of *S. sacchari* are produced on the leaves of some mature cane stalks in abundance but, despite attempts by a number of investigators, no success has been obtained in inducing germination, leading to the conclusion that they play little or no part in perpetuating the disease.

Although *S. sacchari* has a number of alternate grass hosts besides sugarcane (the most important of which is maize) (13) (8) the disease does not seem to be present on alternate hosts in areas where sugarcane is not grown. An important reason for this would appear to be that the disease is not seed borne on such hosts. However, the eradication of such hosts as maize is highly necessary for the control of the disease on cane because it passes rapidly through maize and increases the rate of spread in cane crops. This fact is made use of in the disease resistance trials to be described.

Symptoms

The first symptoms on infected cane appear on the leaves. These are conspicuous by the broad longitudinal white stripes running parallel to the veins and on which red dots appear as the leaves become older (Fig. 6).

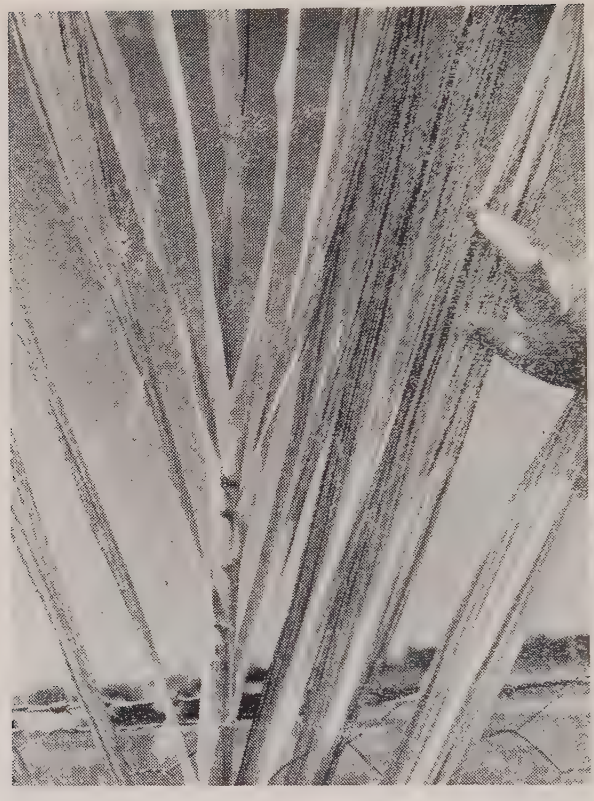

Fig. 6. Leaf symptoms of downy mildew on Argus.
Note striping and dead areas of affected leaves

When the disease is severe and especially when infected cuttings are planted, the whole leaf may be pale yellow in colour and the striping practically unnoticeable. Under favourable conditions of temperature and moisture, minute fluffy lumps like cotton wool appear on the underside of the infected leaves chiefly on the discoloured sections (the " down " of conidia and conidiophores (Fig. 7). As infection spreads over the leaf, the brownish red spots develop extensively giving a rusty appearance to the dying leaf.

The sexual stage of the fungus appears on the first stalks infected and these may be abnormally elongated (" jump-ups "). Oospores are to be found in the shredded tops of such stalks which eventually die completely. Only a small percentage of diseased stalks become oospore bearing in the coolest part of the year. When mature, the oospores are large enough to be just visible to the naked eye.

In Queensland, Leece (8) states temperatures are favourable for conidial production over the period September-May (Spring-summer-autumn) while

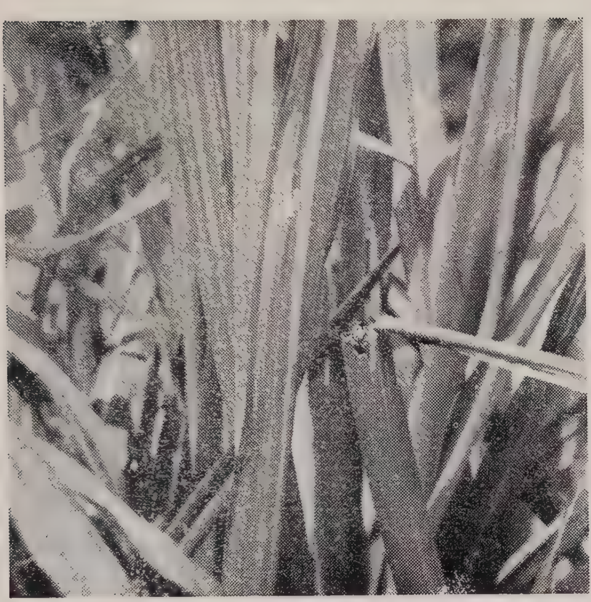

Fig. 7. The " down " or conidia (left) developing on cane leaves affected with downy mildew

Hughes (3) says " the production of conidia occurs only on nights when the temperature does not fall below 65°F." In Fiji, the most abundant production of conidia occurs in the summer wet season, January-March, but less intense production has been observed to take place throughout the whole year. In disease trials, sporadically infected plants are found even in the driest months. A study is at present in progress to determine the effect of environmental factors such as temperature and humidity on the production and germination of conidia. Factors which may create favourable conditions for conidial production over a longer period in Fiji are (1) somewhat higher minimum temperatures than in Australia in the cooler months of the year (2) almost continual dew formation throughout the year at the critical period for sporulation (2 a.m. to 6 a.m.).

Field hygrothermograph readings in 1954 showed rare drops in the minimum temperature as low as 50°F (mean minimum variation winter/summer within 60-72°F) and, very little difference, from season to season, in the maximum humidity reached nightly although the duration of this period varied slightly in a seasonal manner. Nights without dew formation at the minimum temperature—maximum humidity point (about 3 a.m.) were rare exceptions.

The fact that conditions are more consistently favourable for conidial formation than in Australia may explain the less conspicuous nature of the oospore stage in Fiji. The " jump-up " stalks found in the former country during the winter occur very rarely but shredding of leaves subsequent to oospore formation may develop on thin stalks of no undue height quite frequently.

Economic Importance and Control

Again the actual losses caused by this disease are difficult to compute. Susceptible varieties may be so tolerant as to suffer very little loss in yield, while others so badly affected that they are a total loss. In the case of Downy Mildew there has also to be taken into account the serious depletion of sucrose content of tolerant varieties.

The original losses on the Herbert River in North Queensland were probably severe, as the disease increased rapidly from 1910-1913, but no estimation of the damage sustained has been recorded.

The very rapid spread which Downy Mildew may make in susceptible varieties is its most destructive asset, and losses caused by the need for replacement of these by resistant but less suitable types, are probably the most severe. The necessity to assert the strictest control measures, even to the extent of ploughing out large areas, to control outbreaks, also imposes economic hardships.

The most successful means of control of Downy Mildew lies in the use of resistant varieties, although seed selection and roguing play an important part in an area where the disease is not severe and when varieties affected possess moderate resistance.

Downy Mildew, first observed in 1910, increased steadily on the Herbert River from 1913-1915 despite severe control measures. On removal of the susceptible variety B 208 the disease fell markedly in extent year by year and by 1933 had not been observed for 5 years. This district remained clean until 1937 when it again made its appearance in the susceptible variety P.O.J. 2878. Fortunately severe measures were taken for its control, one of which was the restriction in area of P.O.J. 2878, and the disease has not made a reappearance since then although susceptible varieties are grown in this district at present. To maintain the present freedom from Downy Mildew, both in this district and other large areas of northern and central Queensland where valuable but susceptible varieties are being grown, continual vigilance is necessary so that should an outbreak occur it may be promptly brought under control.

In Fiji, Downy Mildew progressed from its original point of entry at Rarawai to other contiguous cane areas on the main island of Viti Levu and also appeared on the island of Vanua Levu. By 1913, two years after it was first noted at Rarawai, it had reached all mill areas except Nausori (on the humid, wet side of Viti Levu). In the years between 1913 and 1930, the disease was kept under control by roguing etc. With the introduction of P.O.J. 2878 about this time, Downy Mildew increased in severity and extent on this variety, despite severe measures for its control. By 1936, it was necessary to reduce the proportion of P.O J. 2878 at Rarawai and to continue this reduction until P.O.J. 2878 was finally eliminated from the island of Viti Levu. Not until then was the disease finally brought under satisfactory control. In 1940, Downy Mildew made its appearance in the variety Argus at

Nausori. Aided by the newly initiated wartime practice of growing maize in cane areas, history repeated itself and this tolerant variety has had to be reduced accordingly.

At Labasa, on the island of Vanua Levu, Downy Mildew had not been found in more than traces for some years and it had been possible to grow P.O.J. 2878 over a limited area. In 1951, the susceptible but promising variety Eros was introduced. In the few years which have elapsed since that period, it has been necessary to discard this variety completely on account of Downy Mildew (and to a certain extent Yellow Spot disease).

Thus it will be seen that in Fiji, Downy Mildew repeatedly threatens to become epidemic if attempts are made to introduce susceptible varieties on a commercial scale. With the exception of Nausori which still presents a Downy Mildew problem, most of the commercial areas are relatively freer from this disease than from Fiji disease, as resistant varieties are principally grown. However, large numbers of seedlings are lost annually in cane breeding activities both in the potted stage and later in the field. Many of these escape infection and only reveal their true susceptibility under the controlled conditions of resistance trials.

CO-OPERATIVE DISEASE RESISTANCE TRIALS IN FIJI

From the foregoing it will be seen that Fiji is probably the most favourable sugarcane centre in the world for the testing of varieties against Fiji disease and Downy Mildew.

Discussions between the Experiment Station of the H.S.P.A. and the Colonial Sugar Refining Co. Ltd., in 1951 resulted in an agreement whereby Hawaiian sugarcane varieties would be tested in conjunction with local varieties against these two major diseases of sugarcane (Fig. 8). It was decided that the testing would be carried out at Lautoka, Fiji, under the direction of the C.S.R. Co.'s pathologist (P.E. Robinson) with periodic consultation and inspection by the pathology staff (J.P. Martin or C.A. Wismer) of the Experiment Station of the H.S.P.A.

Lautoka, is situated on the dry western side of the island of Viti Levu and has a mean annual rainfall of 70 inches, the bulk of which falls in the summer months (January -mid-April), and a mean maximum and minimum temperature of 86°F and 70°F respectively. The location of the resistance trials is central as regards the overall cane area on this side of the island but is semi-isolated from the contiguous cane belt as testing is carried out on the Colonial Sugar Refining Co.'s Lautoka Estate. The latter borders the township of Lautoka on three sides and resistant varieties are grown on adjoining estate fields which act as a buffer between the disease trials and the nearest growers' cane.

QUARANTINE OF HAWAIIAN CANE INTRODUCTIONS

In order to protect the industry in Fiji from the accidental introduction of

DOWNY MILDEW TRIAL
C.S.R. Co. Ltd. & H.S.P.A.
LAUTOKA FIJI Is.

Fig. 8. Area where cane varieties are tested against Downy Mildew at Lautoka, Fiji. Green (left) and P.E. Robinson standing in the picture

pests or diseases not known to be present, Hawaiian cane varieties are first grown for a period of 12 months in field quarantine. The latter is situated on the C.S.R.Co.'s cattle station at Yaqara on the north-west corner of Viti Levu some 50 miles from Lautoka and remote from the cane growing areas.

The annual quota of varieties from Hawaii is received in October-November of each year. Each variety is represented by a few cuttings, the number depending on whether consignment was by sea or air, all of which have received a long hot water treatment of 50°C. for 2 hours or a hot air treatment of 54°C. for 8 hours before despatch from Hawaii. The procedure is as much a precaution against insect pest introduction as against diseases susceptible to such treatment.

After mercurial fungicide treatment, the cuttings are planted and grown for a further 5 to 6 months. The available seed is then replanted to give plots large enough to supply adequate seed for planting disease resistance trials in December of the year following introduction.

Periodical inspections are carried out as a check on abnormality of growth and the presence of pests or diseases. As Yaqara is situated in a dry zone, irrigation is necessary throughout all but the wet months.

The first consignment of Hawaiian canes was received in October 1951, and following 12 months' quarantine was ready for testing in December 1952. Additional consignments have been received since then each year and treated in like manner. Disease resistance trials were installed at Lautoka in December in 1952, 1953 and 1954, and have included also many local varieties at various stages of testing. So far a total of 187 varieties has been tested against Fiji disease and 196 against Downy Mildew by the methods to be described.

FIJI DISEASE RESISTANCE TRIALS

The testing of varieties against this disease poses certain problems in technique and it is only recently that a solution has been found for some of these. This has led to a more efficient transmission of disease throughout the trials. The present method is satisfactory but further improvements are needed to give optimum results.

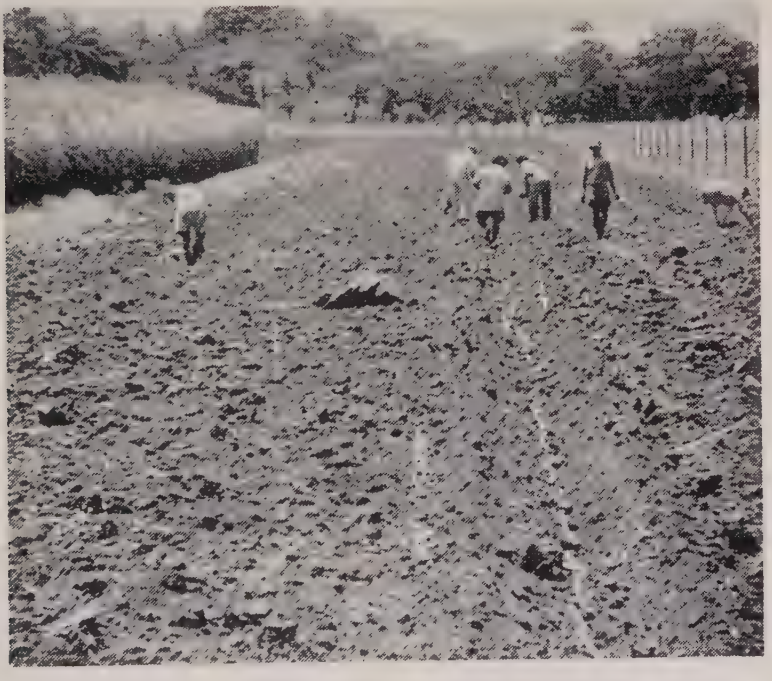

Fig. 9. In the Fiji disease trials the disease carriers or susceptible varieties are planted in rows 18 feet apart. The varieties to be tested are planted later in rows six feet apart, between the 18 foot rows. Every attempt is made to have optimum growth during the peak of the leaf-hopper population so as to secure maximum disease transmission.

Design of the Trials

As there is no way of transmitting Fiji disease mechanically, natural means of transmission per medium of infected leaf hoppers must be relied upon. Provided sufficient leaf hoppers are present in the trial area and healthy test varieties are in close proximity to diseased cane, success in transmission depends entirely on the feeding habits of the vector and its movements. Designs for Fiji disease resistance trials therefore devolve largely on the arrangements of healthy test varieties to diseased cane.

Two types of lay-out were originally tested to gain further information on the special relationships of test varieties to diseased cane. The first, called the Samoan design, consisted of two adjacent rows of test varieties flanked on either side by a row of diseased cane (Fig. 9). The varieties were planted in single row plots 8 feet in length, 6-8 cuttings being used per plot. Five replications of each variety were randomised throughout the trial area so that no two varieties are together more than once.

In the second method, designated the Broadwater method, varieties to be tested were planted in plots four rows x 16 feet in length. 16 cuttings are planted at intervals of 4 feet in the row ; each variety is replicated twice. The line of test variety plots is separated by a row of diseased cane. The comparative sketch below shows the actual difference in layout: —

SAMOAN METHOD

DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD...
......Diseased row
5ft. 2 ft. 4 ft. 2 ft. 4 ft.
11111111——22222222————33333333——44444444———— 5......Variety row
33333333 66666666 77777777 22222222 8......Variety row
————
8 ft.
DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD...
......Diseased row

BROADWATER METHOD

DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD...
......Diseased row
5 ft.
1————1 1 1 2 2 2 2 3 ... Variety row
4 ft.
1 1 1 1 2 2 2 2 3 ... Variety row
1 1 1 1 2 2 2 2 3 ... Variety row
1 1 1 1 2 2 2 2 3 ... Variety row
DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD...
......Diseased row

The Samoan design employs a greater concentration of disease in that every third row is a diseased row whereas in the Broadwater method every fifth row is a diseased row. The additional inner rows of the test variety were incorporated into the Broadwater method as it was considered that this feature would estimate the degree of dissemination of the disease within a variety and thus give a more accurate picture of spread of disease in whole fields of such a single variety.

The two designs were compared in successive years using the same varieties in each. Judging by the results, it cannot be said that one method showed to greater advantage over the other throughout the period of test, each variety tested giving similar degrees of susceptibility by either method. The Samoan method enables a greater number of varieties to be tested in the same area, and the greater disease intensity in the method is probably desirable for purposes of delimiting varieties whose reaction is intermediate between the resistant and susceptible categories. The Samoan method has been henceforth adopted for these reasons.

When considering designs for Fiji trials the possibility of planting alternate diseased plots and healthy plots in the same row was also taken into account. Apart from occasional migratory movements, leafhoppers do not seem to travel far, their flying powers being somewhat limited. Their more natural movement in cane is probably lengthwise along rows rather than across the interrow which might suggest that such a design as this might result in more effective transmission. However, observations in Fiji have indicated that direction of movement is not restricted to any particular pattern provided the interrow spacing is 5 feet or less. As this design had certain disadvantages in regard to establishing diseased cane from diseased cuttings (see later), the refinements indicated by the procedure were not tested by actual trial.

VARIETY USED IN DISEASED ROWS

As the success of the trials depended on establishing a uniform source of infection, the search for a highly satisfactory variety to use in transmitting Fiji disease in resistance trials has been continuous. Two characteristics, not so easily achieved as would be anticipated are required in the ideal for this purpose : (1) ready susceptibility to the disease but not possessing so great an intolerance that plants readily die out at periods after the planting of infected cuttings, (2) a habit of growth and type of foliage sufficiently succulent to attract leafhopper colonization.

After trying a number of varieties, including the wild species " daruka " (? *Erianthus maximus* var) indigenous to Fiji, the variety Kassoer (derived from *S. spontaneum* Java) was finally selected as the nearest approach to this ideal. Unlike the other varieties tried, it was possible to plant diseased cuttings of Kassoer and obtain complete germination. Every cutting gave rise to a diseased stool and after an initial period of slow growth, grew satisfactorily and displayed a suitable tolerance to Fiji disease.

Surveys of leafhopper populations showed that, comparatively, the foliage of this variety, when diseased, did not have the same attraction as that of the healthy test varieties. However, there was no scarcity of hoppers and egg puncture holes on the preferred regions of such plants, and it was concluded that gregarious colonies of nymphs and adults were large enough to permit effective dissemination of the disease. Since this variety has been in use as a source of infection, the degree of transmission has increased markedly.

PLANTING OF FIJI DISEASE RESISTANCE TRIALS

In earlier trials, when both test varieties and diseased cane were planted simultaneously in December each year, the test varieties (mostly vigorous hybrids) grew so rapidly that diseased rows were soon over-shadowed. As leafhopper counts indicated greater numbers on healthy test plants, it was considered a possibility that vector movement might be partially restricted to the dominating foliage of test varieties and therefore, many more leafhoppers might pass their life cycle on healthy cane than on diseased cane with subsequent decrease in transmission. Transmission might also be affected by the test varieties reaching a more resistant stage of growth before much movement of hoppers bred on diseased cane took place. The effect of a wet season on a later planting of test varieties had to be considered in conjunction with the above facts.

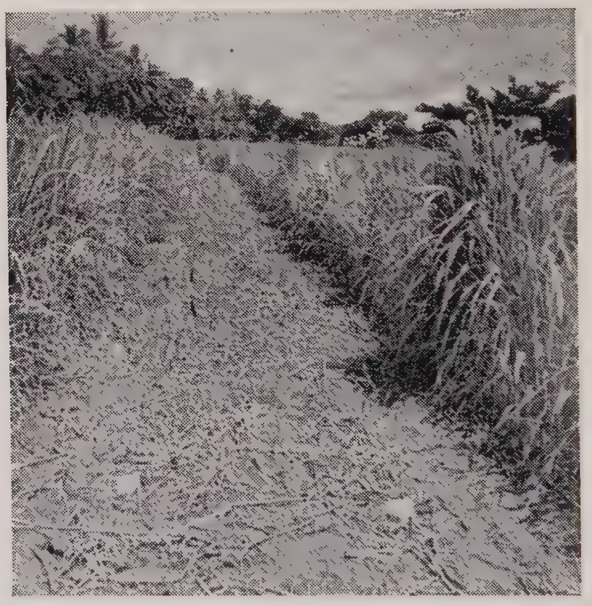

Fig. 10. In the Fiji disease trials the varieties being tested are cut back (ratooned) in their early stage of growth. This method allows the disease carriers to become well established and to force existing leafhoppers to colonize on diseased cane before feeding on the test varieties.

The method finally adopted was to pre-plant the diseased rows ahead of test varieties by some six weeks. In the event of the growth of test varieties still outdistancing diseased cane, the former are ratooned in the early stage of growth but well before the leafhopper peak period in March/April (Fig.10). This procedure has proved desirable for the following reasons : (a) diseased rows become established earlier ; on inspection it can be readily seen whether distribution of diseased plants is even and all supplying can be effected before test varieties are planted (b) any leaf hoppers in the vicinity are forced to colonize on diseased cane prior to germination and following ratooning of test varieties thus ensuring infected colonies.

The timing of ratooning of young plant cane in the test variety rows was indicated by experiment to be quite important. Portion of a trial, 48 plots, (48 different varieties) was ratooned in a block after 5 months growth in May 1954, and again with the balance of the trial which was 11 months of age. The per cent infection in the various varieties twice ratooned was compared with that in the balance of 4 replications ratooned at 11 months only. Several varieties with a highly susceptible reaction in the latter showed no infection when ratooned twice. All other things being equal, it seemed reasonable to infer from this that some infected stalks had been removed before the disease had become systemic. Certainly nothing was gained by ratooning at this period.

Latency of Symptoms

Previous experimental studies by Mungomery and Bell (15), North and Baber (19) and Ocfemia (21) have shown that the incubation period before Fiji disease symptoms may appear varies from a few weeks to many months after infection, and is to a large extent a varietal characteristic.

This period of latency considerably complicates control of disease in the field and raises contentious questions in regard to testing for disease resistance. When disease resistance trials were commenced in Fiji it was considered that favourable biological and climatic conditions might induce an earlier manifestation of disease symptoms in infected varieties. This has proved to be the case in comparison with disease trials cropped in the sub-tropical regions of Australia (N.S.W.). In that region the normal cropping period is 24 months. Trials undergo a plant cycle of two years and disease examinations are carried out in the young ratoons. Experiments attempting to reduce the plant cycle to 12 months showed up in an unsatisfactory light as less disease developed subsequently than with 24 months' cropping. Data had already been accumulated by North (16), showing that little infection took place in cane 12 months of age, and the lack of success in cropping these trials at 12 months was attributed to the disease not having become systemic. In Fiji, two trials have been harvested as plant cane at 11-12 months of age. Consistent examination of these trials in the plant cane stage have failed to bring to light more than an insignificant number of infected stools. On ratooning once, both trials have shown a very large increase in infection, the major portion of which has appeared within a few weeks of ratooning, pointing to the fact that these stools have indeed been infected in the plant cycle. On second ratooning, a similar increase in infection is apparent within a short time. These results indicate that symptoms remain latent in most varieties for many months and raise the question as to what proportion of non-systemically infected stalks are harvested and how much does this interfere with correct interpretation of disease susceptibility which is based on examination of ratoon stools at present? At the present moment, methods of breaking dormancy of this disease are being investigated. Topping of stalks at a certain period in the plant cane cycle, and planting out a proportion of mature stalks from exposed plots, are two of these.

It would seem important that this aspect of Fiji disease should be more fully investigated as a variety, in which the disease makes tardy progress but which remains symptomless, is no less a danger than the more easily infected and easily recognized type. Such symptomless carriers may cause rapid multiplication of Fiji disease when apparently healthy stalks are use for seed, and so intensify the spread of disease that control by roguing is made more difficult.

Assessing Results

The susceptibility of varieties is gauged by comparing the amount of disease in each with that in standard varieties whose reaction is known from long performance in the presence of the disease in the field or in previous resistance trials.

With Fiji disease, the unit of disease is taken to be one infected stool. That is, the presence of one or more stalks with obvious symptoms in a cluster arising from one cutting is considered to denote that the whole cluster is infected as symptoms do not usually become evident until systemic infection has progressed to an appreciable extent. Several examinations of the trial are made and a running total is kept of infected stools/healthy stools for the full number of replications. Surveys are continued, usually at monthly intervals, until the cane reaches a stage of growth too advanced for further inspection.

Results are finally expressed as a total % infected stools and a comparison made with known standard varieties in several classes :-e.g. highly susceptible (— —), susceptible (—), moderately susceptible to moderately resistant (=—;=;=+), resistant (+) and highly resistant (++). The symbols used are those proposed by Martin (11).

Before assigning a final rating to each variety tested, it is considered necessary to plant each in at least two separate trials in successive years. This serves to separate the most susceptible varieties. For those which have not shown any infection and those giving more intermediate results, a further test is often desirable.

The thorough testing of each variety requires 2-3 years, though an indication of susceptibility is often given in earlier tests. Promising seedlings are submitted to Fiji disease tests at a stage far enough in advance of their field extension so that a reliable indication of their resistance may have been gained by the time their expansion on a commercial scale is contemplated.

DOWNY MILDEW DISEASE RESISTANCE TRIALS

Design of Trials

The method used initially was the same as that devised by the Pathology division of the Bureau of Sugar Experiment Stations, Queensland. Briefly, this consisted of planting alternate diseased and healthy test plots in the same row, the former being 9 feet in length and the latter 18 feet. Adjacent rows were placed so that adjoining diseased and healthy plots overlapped as in the following sketch :—

18 ft. Variety
DDDDDDDDD111111111111111111DDDDDDDDD222222222222222222D...
5 ft. 9 ft. disease
DDDDDDDDD333333333333333333DDDDDDDDD4444444...
DDDDDDDDD555555555555555555DDDDDDDDD666666666666666666DD...

Very satisfactory results were obtained with this method in the first trial laid down. However, due to difficulty in obtaining a full stand of Downy Mildew diseased cane in the diseased plots because of repeated poor germination of such material, the design was altered as follows :—

It was decided to plant much the same design as used in the Samoan method of Fiji disease test with slight modifications. The field selected for trial is now prepared for planting with diseased material some 6-7 weeks ahead of the actual time of planting test varieties. The rows of diseased cane are spaced

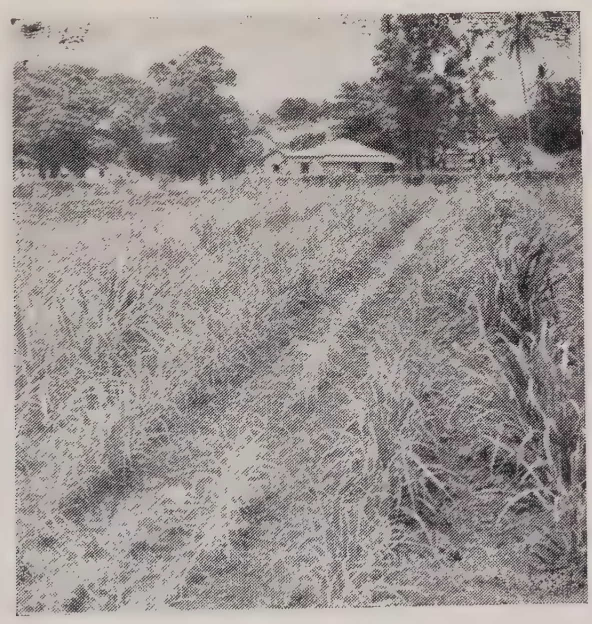

Fig. 11. The second planting of maize (centre) in the downy mildew trial insures a high incidence of disease.

18 feet apart and planted with alternate healthy and diseased cuttings of a number of very susceptible varieties. At this time, lines of maize seed are drilled midway between the diseased cane rows. Prior to the planting of test varieties, supplying of diseased cane rows is carried out. Maize germinates readily, rapidly becomes infected with *S. sacchari* and causes further infection in plants in the diseased cane rows (Fig. 11). At the time of planting test varieties, the infected maize and cane constitute a uniform and highly intense source of disease.

The test varieties are planted in December in 8 foot plots on either side of the diseased maize lines at a distance of 4 feet 6 inches ; 3 to 5 replicates of each variety are randomised in the trial depending on whether the variety has been tested previously or not. The final design of the field is as shown in the sketch below :—

DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD... Diseased cane row

4′6″ 8 ft. Variety
11111111 22222222 33333333 44 ... Variety row

MMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM......Diseased maize row

55555555 66666666 77777777 88 ... Variety row

DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD......Diseased cane row

Time of Planting

As the time of planting is planned for the onset of the wet season, conditions of high humidity and temperature result in profuse production of conidia of *S. sacchari* from the disease source. Germinating test varieties are subjected to this conidial bombardment and the rate of spread is so rapid that results of varietal susceptibility become available during the first few months of the plant cycle.

Assessing Susceptibility

Except when infected in the very early stages of growth, cane does not appear to become systemically infected very rapidly. In a cluster of shoots from a single cutting, separate stalk infections may take place simultaneously. Accordingly, a single infected stalk, rather than a stool, has been found to be a more reliable unit of infection in downy mildew disease resistance trials, and results are expressed as a percentage of infected to total stalks. A stalk is described as infected whether the symptoms appear in the top or in a sideshoot. (Fig. 12).

As in Fiji disease trials, standard varieties of known reaction are used for comparison with test varieties which are classified by the nomenclature and symbols cited on page 1006.

In the course of these trials, certain features have been observed about the way different varieties react to Downy Mildew. There is a range (of tolerance) from very tolerant to highly intolerant. Almost all varieties are more susceptible shortly after germination, even those showing resistance at a later stage of growth. A few have been observed to contract the disease at a later stage of growth, and, of these, some show bud infection and side-shooting, but not top infection.

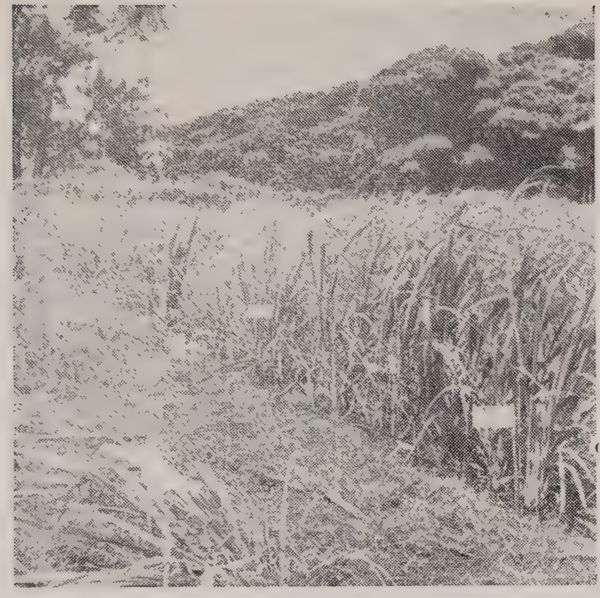

Fig. 12. In the downy mildew trials, showing healthy N. Co. 310 in the foreground with diseased 49 R 3863 in the background

It is evident that there are a number of factors entering into varietal resistance, some of which are probably biochemical and others morphological. Studies are in progress at present to discover which factors are important in resistance and whether the manner in which disease resistance tests are carried out takes into account such factors.

In actual practice, the method of estimating Downy Mildew resistance in these trials gives a very reliable indication of the manner in which such varieties would react when exposed to the disease under sporadic or epidemic conditions. For the exceptional few, it is desired to enquire further if resistance is of an escapist nature, e.g. whether growth habit is such that the early stages of susceptibility are quickly passed, or whether some morphological feature, such as trash clinging more tightly to the young buds, gives preferential protection against infection.

Results from these investigations will not be available for some time, but preliminary studies have brought to light some interesting data. For instance, in an experiment in which the apparently immune variety Kassoer was used, buds of various ages were temporarily exposed to infection. Some buds were softened by water treatment, on some the outer bud scale was removed, and the remainder were left untreated. At the time of writing, infection has been recorded only on the shoots arising from buds from which the outer scale was removed. The leaves of an infected shoot show a distinct symptom pattern which has been associated with leaf infection in highly resistant varieties. In these cases, infection does not seem to advance into the stalk, and, on the leaves, conidia are produced very sparsely *only* in the first stages of infection or not at all, though striping may persist for some time. A protoplasmic type of resistance might be inferred, but not proved, from this reaction.

Infection may remain dormant in buds for some time. This was shown by topping stalks in a portion of one trial showing very light infection. Infected sideshoots were produced in profusion and much infection was detected where little or no disease had been recorded previously. In this case, infection may have taken place subsequent to sideshooting, but was unlikely considering that topping was carried out in the middle of the dry season. Further, there was no large increase of infection in the ratoon shoots of some plots of susceptible varieties harvested at ground level.

It has been found that one trial suffices to separate susceptible and resistant varieties. Those in the moderately susceptible to moderately resistant classes are given a second test.

THE RELATIVE RESISTANCE OF SOME IMPORTANT VARIETIES TO FIJI DISEASE AND DOWNY MILDEW AS DETERMINED IN FIJI

Commercial Hawaiian Varieties	Reaction to		Percent of Total Acreage (1954)
	Downy Mildew	Fiji Disease	
37-1933	++(1)	=+	32.60
44-3098	—	—	24.58
38-2915	=—	——	17.71
32-8560	++	—	5.81
32-1063	=+	——	5.80
39-7028	++	=	3.97
39-3633	+	+	3.07
38-4443	+	——	1.63
41-3340	=	——	0.93
39-4753	+	——	0.60
			Total 96.70
Commercial Fijian Varieties			
Badila	+	+	Commercially Important
Pindar	+	=—	do.
Ragnar	+	++	do.
Mentor	=	++	do.
Castor	=	+	Promising
Luna	++	=—	do.
39MQ 841	——	+	do.
39MQ 832	—	++	Important for Breeding
Trojan	—	+	do.
Uba Marot	——	++	do.

(1) Symbols : + or ++ Resistant or highly resistant : =+ moderately resistant ; = average resistance ; =— moderately susceptible ; — or —— susceptible or highly susceptible.

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In the absence of the authors the following paper was presented by Mr. N. J. King.

Paper

SOME FURTHER DEVELOPMENTS IN THE STUDY OF RATOON STUNTING DISEASE IN QUEENSLAND

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and
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DISTRIBUTION AND IMPORTANCE

Since a paper on the subject of ratoon stunting disease was presented to the 8th Congress of the International Society of Sugar Cane Technologists in 1953 (2) this disease, as well as being present in Queensland, has been recorded in most cane-growing countries of the world. These include New South Wales, British West Indies, Florida, Louisiana, Puerto Rico, Colombia, Mexico, Hawaii, Taiwan, India, South Africa and Mauritius, and in many of these places it is believed to be causing serious yield losses in the cane crops. No doubt actual yield figures will confirm this belief, as they have already done in a series of field trials set out in various parts of Queensland.

The results of trials in which yields from replicated plots of diseased and healthy Q. 28, the variety in which the disease was first recognised, have been published previously (2,4). They revealed considerable losses in yield due to the disease in both plant and ratoon crops, as also did small observation plots of a number of other varieties.

Following a state-wide survey in 1952, which revealed the presence of ratoon stunting disease in all Queensland cane-growing districts, a comprehensive series of trials was planted in 1953 and 1954 in an effort to determine the losses caused by the disease in all important canes of both tropical and sub-tropical districts. Observations throughout the growth of the plant crops of the 1953 trials showed that, where differences did occur, germination and early growth was poorer in the diseased plots, and the ultimate length of stalks in these plots was less than in healthy cane. No differences were observed in thickness of stalks in the plant crops, nor in the number of shoots produced per stool in the diseased and healthy plots, as was the case with the early trials with Q. 28. However, these latter trials were carried out in a dry year when effects of the disease were at their worst, while the current series of trials received favourable growing conditions.

Harvest results from the plant crops of the 1953 trials showed that varieties such as Pindar, P.O.J. 2878, Trojan, N.Co. 310 and Vidar suffered considerable losses in yield (see Table I). Q. 50 suffered some loss in one trial in South Queensland, while Badila. Comus and S.J. 16 did not show consistent losses, indicating that some of these varieties, at least, may exhibit a tolerance to the disease, though here again favourable conditions for growth may have influenced these results.

TABLE I

YIELDS OF DISEASED AND HEALTHY PLOTS IN REPLICATED TRIALS (PLANT CROP)

	Tons per acre					
	N. Co. 310	Pindar	P.O.J. 2878	Q. 50	Trojan	Vidar
Healthy	34.75	47.9	30.75	46.1	45.8	39.17
Diseased	28.30	40.9	26.3	46.4	34.3	35.00
Loss	6.45	7.0	4.45*	...+	11.5	4.17
Healthy		41.7		36.8	43.2	
Diseased		35.8		35.0	33.4	
Loss		5.9		1.8+	9.8	
Healthy		25.1		32.1	37.0	
Diseased		21.9		27.65	29.6	
Loss		3.2*		4.45*	7.4	
Healthy					37.56	
Diseased					33.44	
Loss					4.12	

*Difference significant at 5 percent level.
+ Difference not significant.
All other differences significant at 1 percent level.

The reaction of Q. 50 is of interest since it bears out observations in the field, viz. that this variety is tolerant to the disease in the Mackay district, but suffers losses in South Queensland, particularly on the drought-liable slopes in the Isis area. Sugar content was determined in all trials but no significant differences were found, although of course differences in yield gave corresponding differences in total sugar per acre.

Results from ratoon crops of these trials are not yet available, but indications are that losses from some varieties, such as N.Co. 310, Pindar, P.O.J. 2878, Trojan and Vidar will be severe, and some may even be of the same order as in Q. 28. Varietal resistance trials have also shown that the disease can cause serious losses in a wide range of commercial canes in Queensland (see Table II).

TABLE II

REACTION OF THE MORE IMPORTANT QUEENSLAND VARIETIES TO RATOON STUNTING DISEASE

Variety	Yield Losses	Symptoms in Nodal Vascular Bundles
Badila	Moderate	Variable
C.P. 29-116	Small	Often difficult to find
Co. 290	Moderate	Obvious
Co. 301	Small	Obvious
Comus	Small to moderate	Variable
Eros	Small to moderate	Obvious
M. 1900	Severe	Variable
N. Co. 310	Severe	Obvious
Pindar	Small to moderate	Obvious
P.O.J. 2725	Moderate to severe	Variable
P.O.J. 2878	Severe	Variable
Q. 28	Very severe	Obvious
Q. 42	Severe	Obvious
Q. 44	Small	Obvious
Q. 45	Severe	Obvious
Q. 47	Moderate	Variable
Q. 49	Severe	Obvious
Q. 50	severe in Sth. Qld.	Variable
	Small in Cen. Qld.	Often difficult to find
Q. 51	Severe	Obvious
Q. 55	Severe	Obvious
Q. 813	Severe	Often difficult to find
S.J. 2	Severe	Often difficult to find
S.J. 4	Severe	Variable
S.J. 16	Severe	Obvious
Trojan	Severe	Obvious
Vesta	Severe	Variable
Vidar	Severe	Obvious

CONTROL

Investigations into. and the practical application of, the control of ratoon stunting disease by subjecting the setts to hot-water treatment have been intensified during the past two years.

As a result of early experimental work with Q. 28 it was recommended that diseased setts should be treated in water at 54° C. for one (1) hour or 52° C. for one and a half (1 ½) hours. However, the application of these treatments to a number of varieties soon showed that many were not as tolerant to hot water as Q. 28, and that a treatment at 50° C. for two (2) hours was less detrimental to germination. Therefore, when large-scale treatment got under way in most districts during the 1953 planting season this latter treatment was adopted as standard practice.

During 1953 approximately 2,000 tons of cane were hot-water treated, and this provided good supplies of plants for 1954. However, many difficulties arose in treating large weights of plants, and in some instances batches received inadequate treatment. Most treatment tanks had to be improvised from material available, and in many cases circulation was inadequate. Since farmers were accustomed to handling setts in bags, most of the treatments were done in these bags which are of a heavy jute fabric. Under the circumstances it was not surprising that circulation within the bags was insufficient to ensure that every sett received the full treatment.

In order to ensure that all setts in a tank receive the required treatment a great deal of attention has been paid to the construction of tanks and containers for the setts. It is now recommended that the ratio of plants to water in the tank should not be greater than one to six or seven ; that is, a typical tank of 1,400 gallons would have a capacity of about one ton of plants. Tanks should be fitted with a circulation pump with a capacity sufficient to circulate the entire tankful of water at least six times an hour. The water is drawn from pipes at the bottom of the tank which are usually below the false bottom on which the baskets of setts rest, and forced through holes in pipes along the top on the return. The source of heat must be adequate to meet all likely demands from the tank. Steam is most commonly used and is either blown directly into the water, or passed through a heating coil at the bottom of the tank. The installation of a thermostatically controlled steam valve of high precision adds considerably to the ease of operation of the tank.

The most suitable containers for the setts are all-metal baskets consisting of a flat-or round-iron frame of suitable strength, covered with galvanized wire netting of a sufficiently small mesh to prevent setts passing through it. They are completely enclosed to prevent setts escaping while immersed in the water, and are filled by opening a complete side or top. They vary in size to hold up to 200 lbs. of cane which should be just tumbled into the basket without any attempt to stack it. This allows a better circulation of water within the container, and the proper temperature is reached at the centre of the mass in one to seven minutes (5).

Each treatment plant should be tested thoroughly to be certain that the circulation is satisfactory and that the temperatures are uniform throughout the loaded tank. A glass mercury thermometer fitted into a brass case some four feet in length was found suitable for this purpose. The length and weight of the mercury means that these thermometers have always to be calibrated and used in the vertical position, but even with this limitation, they have proved satisfactory in determining temperatures at various points in the water and in the sett container. Once it is established that the treatment plant is efficient, the temperature may be controlled during operational runs by using a thermometer inserted in the circulating system near the pump on the outside of the tank. A typical treatment tank is illustrated in Figure 1.

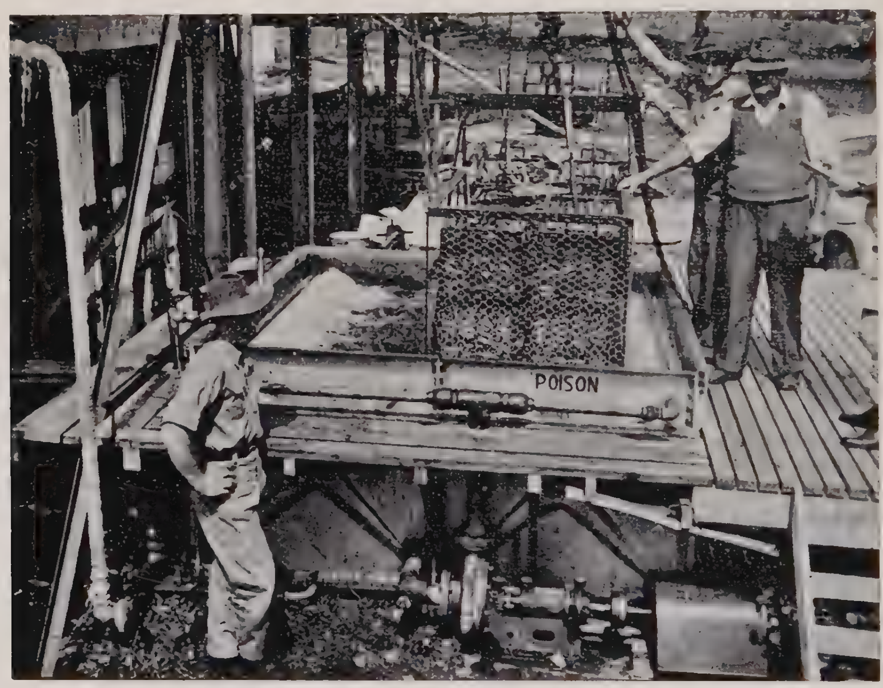

Figure. 1. Baskets of cane plants being loaded into a hot-water treatment tank in North Queensland.

Even with accurately controlled treatments, as provided with the above mentioned tanks, there was reason to believe that a very small percentage of setts in some varieties was escaping the curative effect of treatment at 50°C. for two hours. A series of trials was therefore set out in which a number of varieties infected with ratoon stunting disease was treated in hot water at 50°C. for two, two and one-half and three hours, 51°C. for two hours, 52°C. for one and one-half and two hours and 53°C. for one and one-half hours. Germination results showed that treatments up to three hours at 50°C., two hours at 51°C. and one and one-half hours at 52°C.

were not unduly detrimental with most varieties, but more severe treatments are likely to lead to a serious falling off in germination.

The effects of these treatments have not been fully determined, but they appear to have confirmed that a small percentage of setts escaped the curative effect of 50°C. for two hours. The indications also are that there is a decline in the number of " escapes" with an increase in either time or temperature, but these increases are, of course, strictly limited by the ability of the plant to survive, and it appears at present that an increase in time is preferable to an increase in temperature. The reason why certain setts are not cured is not known, but it is considered that some physical property of the setts, such as thickness, woodiness or pithiness could be responsible. On the other hand, the possibility that secondary spread, by insects or other means, could be responsible for this apparent "escape" from the curative treatment, is not being overlooked, and a series of insect transmission studies is under way.

In spite of the above findings it is confidently believed that most of the cane which was treated at 50°C. for two hours for commercial plantings in 1954, is now free from the disease. The planting material will prove of great value to the farmers by increasing yields, and assisting in the ultimate eradication of the disease.

Another important factor in the elimination of the disease is the effective sterilization of knives and other cutting implements in order to prevent re-infection of the treated cane by these instruments. Heat is quite effective either in the form of hot water or fire, but its practical application in the cane fields presents some difficulties.

A number of disinfectants and other compounds have therefore been tested for their ability to inactivate the virus. In testing these compounds solutions were prepared of such a strength that the addition of an equal volume of diseased juice gave the required concentration. The mixtures were allowed to stand for ten minutes before pressure inoculation into healthy setts of Q. 28 which were subsequently planted and grown to maturity. The results which were based on the occurrence of discoloured vascular bundles are set out in Table III.

Those compounds which inactivated the virus and which were considered to have some possible practical application were again tested in the presence of an organic mercurial solution of the normal strength, and it was found that this had no detrimental effect on their efficacy. It was considered that the presence of a suitable antiseptic in mercurial dipping tanks or in the mercurial solutions used in the spray systems of some cutter planters might counteract any knife transmission which had taken place during the cutting of plants. Accordingly an experiment was set out in which healthy setts of Q.28 were inoculated by cutting with a knife contaminated with diseased juice. These setts were then immediately dipped in various antiseptics for a period of ten seconds, which is about the normal time of exposure to mercurial solutions, and planted for observation.

TABLE III

EFFECTS OF ANTISEPTICS AND OTHER COMPOUNDS ON RATOON STUNTING VIRUS

Materials which inactivated the virus after 10 min. exposure		Materials which failed to inactivate the virus after 10 min. exposure	
Alcohol (ethyl)	50%	Acriflavine	0.2%*
" Aretan "	3%*	" Aretan "	1%*
Calcium hypochlorite	10%	Boric Acid	5%
" Dettol " (chloroxylenol)	0.5 to 2.5%	Formaldehyde	2%
Formaldehyde	4%	Lysol	0.1%*
" Lysol "	0.5 to 2.5%*	Sodium benzoate	2%
Mercuric chloride	0.1%	Sodium carbonate	10%
Phenol	1 to 2.5%	Sodium phosphate (Na_3PO_4)	5—10%
Phenyle	1.66 to 2.5%*	Phenol	0.05—0.1%
Potassium permanganate	1%	Potassium permanganate	0.1%
Zephiran	0.05 to 0.5%	Tannic Acid	3%

Potassium chlorate 5% caused a germination failure.
*Percentage of Commercial product. Others percentage active principle.

In all cases the resultant plants were diseased, indicating that knife infection cannot be counteracted by a short dip in a disinfecting solution.

Experiments are still in progress to determine the minimum safe treatment for the sterilization of knives with antiseptics such as Zephiran, Dettol, Lysol, Phenyle and Phenol, but it is confidently felt that a swabbing or scrubbing in solutions of the strengths listed in Table III as being effective in inactivating the disease in juice, followed by a short soak, will be a safe method of disinfection.

TRANSMISSION STUDIES

Studies on the distribution of the virus within the host show that it occurs in leaves, stems and roots. Dilutions of juice extracted from these parts of the plant show that the concentration of the virus is approximately the same in all parts, and that the virus will remain infective at a dilution of approximately one part in 10,000.

In addition to inoculations into setts and young growing stems, it has been shown that ratoon stunting disease is easily transmitted by inoculations of the roots of young plants. This can be done by carefully exposing the young roots, without any intentional bruising, then inoculating them either by pouring diseased juice over them, or by cutting with a knife smeared with diseased juice, or by cutting them under the surface of diseased juice. A high percentage of infection was obtained in each case.

STRAINS

The possibility that different strains of the disease might exist in Queensland is being investigated. The different reactions of certain varieties in different districts, and the varying intensity of symptoms from one district to another suggest that this could be the case. Infected material has been collected from the main cane-growing districts and inoculations have been made into the varieties Q. 28, Q. 44, Q. 50 and G. 176. From the intensisty of symptoms produced there are indications that at least some variations occur.

ALTERNATIVE HOSTS

Experiments have been carried out to determine the host range of ratoon stunting disease. Inoculations have been made into the following plants :- Tomato (variety Q. 2), Zinnia (Lilliput), *Nicotiana glutinosa*, tobacco (Hickory Prior), *Emilia sonchifolia*, vegetable marrow (Long Cream Runner) and egg plant (Black Beauty). In all cases the inoculation was done by gently rubbing a mixture of freshly expressed juice and celite over the surface of all leaves except the very young and old. The plants were grown to maturity without showing any abnormality. Tobacco plants infected with tomato spotted wilt, and tobacco and *Nicotiana glutinosa* plants infected with cucumber mosaic were used as sources of inoculum for the pressure inoculation of setts of Q. 28, but the resultant cane plants showed no evidence of ratoon stunting disease. A number of plants belonging to the gramineae has also been inoculated with ratoon stunting disease, usually by means of a hypodermic needle into the young stem and growing point region. These plants include a number of varieties of maize, sorghum, sudan grass, wheat and oats, as well as several other grasses. In no case did inoculation produce any observable effects on any of the plants when grown to maturity. However, the virus was recovered from maize, sorghum and sweet sudan grass, by inoculating extracts from these plants back into setts of Q. 28. All inoculations from wheat and oats were negative, while results from other grasses are not yet available. The fact that the virus can exist in plants other than sugar cane, and that it can re-infect sugar cane when artificial inoculations are made from these plants, is of interest, but it does not necessarily mean that these plants will become diseased in the field, and act as a source of infection for sugarcane.

DIAGNOSIS OF THE DISEASE

Further attempts have been made to discover a readily applicable method of positive diagnosis of the disease. Various preparations of diseased sap have been examined with the ultra-violet absorption spectrophotometer and electron microscope, without showing any definite evidence of the presence of a virus. Studies on the purification of the virus, combined with inoculations into Q. 28 at various stages of extraction, indicate that it is a difficult one to separate from the normal plant constituents by the more common methods of virus purification.

Considerable amounts of virus are thrown down with other plant material when infective sap is subjected to low-speed centrifugation. Further amounts are precipitated by the usual clarification process using three percent dipotassium hydrogen phosphate (K_2HPO_4), while one half saturation with ammonium sulphate precipitates all the remaining virus. The virus passed through a No. 41 Whatman filter paper in high concentration, but was retained on a "Chamberland I.F." filter candle. Ultra centrifuge studies are at present in progress.

The most important observation made recently in the field is that young diseased plants of some varieties, particularly Q. 28 and Q. 44, show characteristic internal symptoms within about two months of planting, when growing conditions are good. If a young shoot is split longitudinally, the immature nodes, up to within one half inch or so of the growing point, show an unmistakable general salmon-pink colour ; however, the discoloured vascular bundles seen in more mature diseased stalks are usually absent. Some healthy shoots show a slight discolouration but in these it is confined to near the rind, while in diseased shoots the colour occurs at the centre of the node. The surface exposed should be examined as soon as possible after cutting, for oxidation effects quickly mask the pink colour. It is advisable to cut the shoots only in bright, natural light and, if possible, a known healthy shoot should be examined at the same time. The discolouration in immature tissue does not show consistently in young ratoon shoots, but it can be found in young plant shoots so small that the stalk tissue is only two inches or so in length and the growing point well below ground level. This symptom in young cane can be of value in allowing an early check on commercial plantings, but it is of most importance in experimental work since it may make possible at least two, and sometimes three, cycles from planting to examination within the one growing season.

It should be pointed out, however, that the absence of symptoms at this early stage does not necessarily mean that the plants are healthy, particularly in inoculated cane where very small amounts of inoculum might have been used. Consequently, in experimental work, all plants which do not show symptoms in the early stages of growth should be grown to maturity or near maturity before any definite conclusions are drawn. On the other hand, if symptoms do show at an early stage they can be relied upon as a definite indication of the disease. This discolouration in immature tissue does not always show in young nodes at the top of mature stalks.

The symptoms still most extensively used for diagnosing the disease are the discoloured vascular bundles occurring in the lower sections of the nodes of relatively mature portions of the stem. These reddened vascular bundles were first mentioned as a reliable indication of the presence of the disease in 1952 (3) although they had been observed some time before, and have been described in detail since (1). The large leaf traces seem to be most affected, possibly because their structure is such that the gummy substances which cause the discolouration cannot pass freely through them. Many of the other large branching nodal bundles are also affected, and microscopic examination shows that the xylem elements are clogged, and that parts of the phloem are also deranged (see Fig. 2).

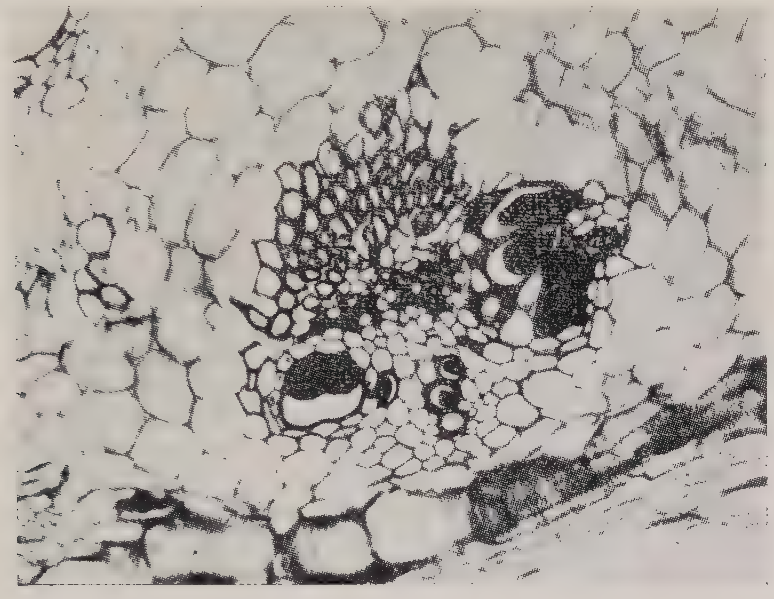

Fig. 2 (a) Cross section through node of cane stem infected with ratoon stunting disease, showing clogging of a vascular bundle. X 115.

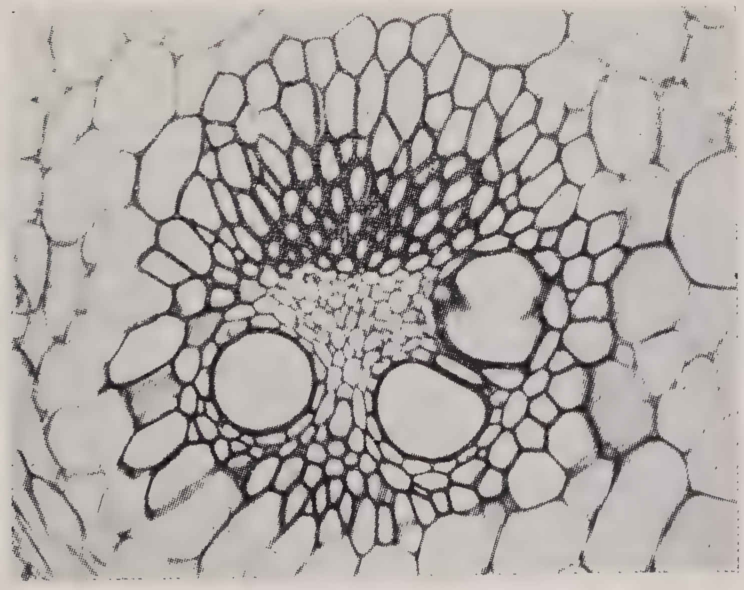

Fig. 2 (b) Cross section through normal vascular bundle at node of healthy cane stem. X 115.

Another important finding concerning the diagnosis of ratoon stunting disease is that, in plant cane, it is generally only necessary to examine a primary shoot. The disease will not normally show in secondary shoots unless it also shows in the primary and, conversely, it may show in the primary but not be apparent in the others. This fact is of considerable value when examining both experimental and commercial plantings, since, combined with the selection of smaller stools, it increases by several times the chance of choosing a stalk showing symptoms, when compared with selection of stalks on a purely random basis. On the other hand, there does not appear to be any correlation between the early development of stalks in the ratoon stool and their production of symptoms compared with that on the later developing stalks.

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DISCUSSION

To a query from Mr. Kirtikar, Mr. King replied that the range of reaction of various varieties to different temperatures with regard to Hot Water Treatment was great. A variety from South Africa showed 100% germination even when treated with Hot Water at 55°C. for three hours, while a local variety died out when treated at 50°C. for two hours. Regarding the cost of the treatment in Australia, he remarked that it was difficult to give precise figures but as this was done by the factory under the direction of Cane Pest and Disease Control Board, it was almost free for the cultivators, the only cost involved being that of transport of the seed material. As the treatment was done by the factory in Scrap tanks, they had, in Australia, taken to Hot Water Treatment instead of Hot Air Treatment recommended in Louisiana.

Dr Han Lioe Hong then presented the following paper.

Paper

FUSARIUM-POKKAHBOENG RESISTANCE TRIAL

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INTRODUCTION

Fusarium pokkahboeng[1] in sugarcane was known in Java for many years and the first descriptions by Wakker and Went (7) date back to 1896.

During the first quarter of the present century this abnormality was of little commercial importance with the canes of noble blood (*S. officinarum*) then grown. But when these were replaced by seedlings of the third glagah (*S. spontaneum*) nobilization *pokkahboeng* became one of the major diseases of Java, especially with P.O.J. 2878.

In 1927 Bolle (1) proved that *pokkahboeng* is caused by species of *Fusarium*, of which *Fusarium moniliforme Sheldon* and its variety *Fusarium moniliforme Sheld. var. subglutinans Wr. et Rg.* are the most prevalent. Bolle (2) also discovered the natural way of infection. During the unfolding of the young leaves of the spindle leaf-2[2] is rolled up inside leaf-1. At a certain time during the unfolding of leaf-1, its inside edge lies along the outside edge of leaf-2 in such a way that a sort of funnel is formed. Fusarium spores in rainwater or guttation droplets may be washed in through this funnel and so reach the bases of -1 and -2 leaves, where they germinate. The mycelium passes through the still soft cuticle of these leaves to the inner tissues, and can reach the stalk and attack the growing point. The rate of growth, the frequency with which the funnel stage occurs and the degree of guttation determine, especially in the dry season, the intensity of the Pb-infection[3]).

So the fusarium-conidia must reach the bases of the young leaves -1 and -2 to cause an infection. The susceptible parts can also be reached by injecting the spindle above the growing point with a suspension of fusarium-conidia. To obtain good results we have to inoculate the young tissues of the young leaves ; the higher the spindle is inoculated the less infections we get (at 5 cm. below the leaf joint + 1 for example the percentages of infection, especially for the stadia Pb_2 and Pb_3, are low) and at last the plant will not become infected at all.

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(1) The Javanese word "pokkahboeng" indicates a shoot (boeng) the top of which is distorted.

(2) According to the nomenclature of Kuyper (6) the highest visible leaf joint and the whole leaf at that joint were given the notation + 1. The older leaves were numbered + 2, + 3, + 4, etc., while the younger ones received the numbers 0, —1, —2, —3, —4, etc.

(3) We can distinguish 3 stadia of Pb-infections :

Pb_1 : only leaf-symptoms, chlorosis with or without red markings and with or without wrinkling and splitting of the leaves.

Pb_2 : Stagnation by pb, ladder-shaped lesions in the stalk, sometimes these ladders run near to the surface of the stalk rind and break through, thus causing local malformation of the stalk.

Pb_3 : Toprot by pb.

The damage is chiefly caused by Pb_2 and Pb_3.

Before the second world war inoculations at 10 cm. below the leaf joint +1 were used for testing sugarcane varieties for their susceptibility and sensibility to Fusarium-pokkahboeng. The susceptibility was measured by the percentage of Pb-total (Pb_1+Pb_2+Pb_3) and the sensibility by the percentage of (Pb_2+Pb_3).

In a field trial we have investigated the reliability of this inoculation-method using the two main sugarcane varieties P.O.J. 2878 and P.O.J, 3016 whereby inoculations at 15 and 20 cm. below the leaf joint + 1 were also tested.

The purpose of this paper is to present the results of this field trial.

MATERIALS AND METHODS

The experiment was designed as a split-plot lay-out with 6 replications for each treatment. Each block was divided in 2 sub-blocks (sugarcane varieties) with the 4 treatments (non-treated, inoculation at 10,15 and 20 cm. below leaf joint +1) in each sub-block. The treatments were randomized in the sub-blocks.

Each plot had 4 furrows, one metre apart and 6 metres long. The sugarcane planting material consisted of 2-eye seed pieces. Ten seed pieces were planted per furrow. The plots were planted on 11th August, 1954. One row of canes of the variety P.O.J. 3067 was planted between the plots to serve as a buffer.

At an age of 3½ months the plants were inoculated on four successive days viz. P.O.J. 2878 on 24th and 26th November 1954 and P.O.J. 3016 on 25th and 27th November 1954. The conidia-suspensions were prepared daily by rinsing ten test-tubes with 1 month old cultures of fusarium on rolled oats agar with 300 ml sterile water. Per injection the spindle was inoculated with 0.3 ml of the conidia-suspension with the aid of an injection-syringe.

In each plot 30 plants were inoculated.

DISCUSSION

The mean percentages of pokkahboeng-infections [% Pb-total and % (Pb_2+Pb_3)] of the different treatments are given in Tables I and II (left the original and right the transformed data).

Very important was the fact that both the percentages of Pb-total and the percentages of (Pb_2+Pb_3) of the individual observations caused by each of the three treatments of inoculation showed little fluctuations about the treatment means (Tables I and II).

TABLE I

DIFFERENCES IN % Pb-TOTAL BETWEEN P.O.J. 2878 AND P.O.J. 3016 FOR THE DIFFERENT TREATMENTS (LEFT THE ORIGINAL AND RIGHT THE TRANSFORMED DATA)

Treatment	P.O.J. 2878	P.O.J. 3016	Difference	P.O.J. 2878	P.O.J. 3016	Difference
Non-treated	11,7±1.7	10,4±1,7	1,3	19,8±2,7	18,1±2,7	1,7
Injection at 10 cm.	94,4±1,7	96 ±1,7	—1,6	79,2±2,7	80,8±2,7	—1,6
,, ,, 15 ,,	98,9±1,7	97,7±1,7	1,2	86,5±2,7	82,9±2,7	3,6
,, ,, 20 ,,	99,5±1,7	96,6±1,7	2,9	88,2±2,7	82,6±2,7	5,6
Least significant differences for comparison at 5-per cent point	...	...	5,9	... ...	... ...	9,2

TABLE II

DIFFERENCES IN % (Pb_2+Pb_3) BETWEEN P.O.J. 2878 AND P.O.J. 3016 FOR THE DIFFERENT TREATMENTS (LEFT THE ORIGINAL AND RIGHT THE TRANSFORMED DATA)

Treatment	P.O.J. 2878	P.O.J. 3016	Difference	P.O.J. 2878	P.O.J. 3016	Difference
Non-treated	2,8±3	1,1±3	1,7	7,7±2,8	3,5±2,8	4,2
Injection at 10 cm.	71,1±3	35,7±3	35,4	57,6±2,8	35,9±2,8	21,7
,, ,, 15 ,,	80,3±3	50,6±3	29,7	67,0±2,8	45,4±2,8	21,6
,, ,, 20 ,,	90,6±3	57,0±3	33,6	72,6±2,8	49,2±2,8	23,4
Least significant differences for comparison at :						
5-percent point	... ...	... ...	15,9	...	... ...	11,2
1-percent point	... ...	... ...	21,5	...	... ...	15,1

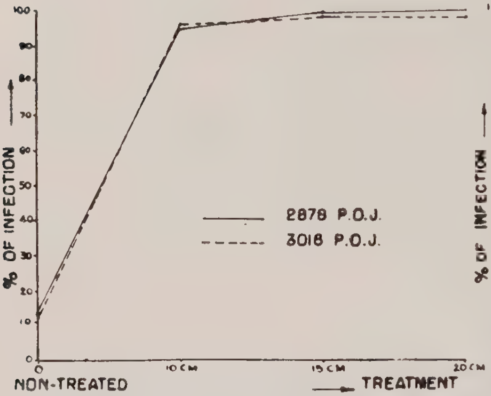
With both varieties the influence of inoculations at 10,15 and 20 cm. below the highest visible leaf joint of leaf+1 on the percentage of Pb-total and (Pb_2+Pb_3) was significant at the 0,1% point.

The percentages of Pb-total caused by inoculation at 10,15 and 20 cm. below the leaf joint +1 were about equal as well for P.O.J. 2878 as for P.O.J. 3016 In this respect the differences between the two varieties were not significant (see Table I and Graph 1). So we can conclude that eventual differences in susceptibility between the two varieties cannot be proved by these inoculation-methods.

As regards the differences in percentage of (Pb_2+Pb_3) between the varieties P.O.J. 2878 and P.O.J. 3016 both inoculation at 10,15 and 20 cm. below the leaf joint +1 gave about the same results (see Graph 2). These differences in sensibility were significant at the 1% point (Table II).

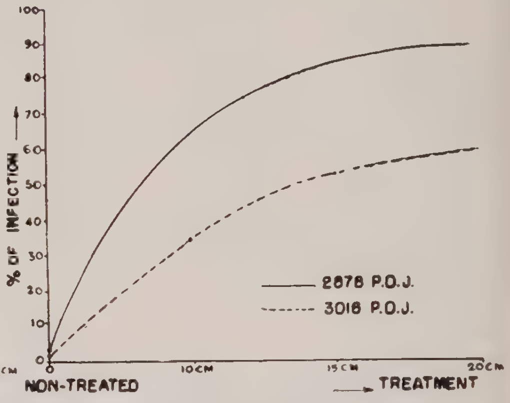
GRAPH I

MEAN % Pb TOTAL OF THE DIFFERENT TREATMENTS



GRAPH 2

MEAN % $[Pb_2 + Pb_3]$ OF THE DIFFERENT TREATMENTS



From the above-mentioned we can conclude that although the two varieties were equally susceptible (94,4%—99,5%, Pb-total) P.O.J. 2878 was more sensitive than P.O.J. 3016. Moreover inoculations at 10,15 and 20 cm. below the leaf joint+1 gave about the same differences in sensibility between the two varieties. It is desirable to inoculate the spindle as high as possible above the growing point as this agrees more with the natural way of infection.

For these reasons inoculation at 10 cm. below the highest visible leaf joint+1 is recommended for the testing of sugarcane varieties with regard to *Fusarium-pokkahboeng* infection.

NATURAL Pb-INFECTION

In Table III the percentages of (Pb_2+Pb_3) of the varieties P.O.J. 2878 and P.O.J. 3016 in the variety trials of the years 1939 and 1941 are given (4,5).

TABLE III

PERCENT (Pb_2+Pb_3) IN THE VARIETY TRIALS OF THE YEARS 1939 AND 1941

Number of trials	Average % (Pb_2+Pb_3) 1939 P.O.J. 2878	1939 P.O.J. 3016	1941 P.O.J. 2878	1941 P.O.J. 3016
52	10,2%	2,9%	—	—
97	—	—	2,4%	1,9%

The percentages of Pb-infections in the 1955 crop which we received from the sugarcane estate "Sindanglaoet" (Cheribon, West-Java) are given in Table IV.

TABLE IV

PERCENT (Pb_2+Pb_3) ON THE SUGARCANE ESTATE " SINDANGLAOET " (1955)

Variety	Number of furrows	Number of stalks	1st Count (5-10/1-55)	2nd Count (17-21/1-55)	3rd Count (7-15/2-55)
P.O.J. 2878	600	33749	7,09	9,01	10,03
P.O.J. 3016	420	25267	4,13	5,49	6,69

From Tables III and IV we can conclude that in the field P.O.J. 2878 becomes more severely diseased than P.O.J. 3016.

By comparing the results obtained with artificial inoculation of sugarcane plants at 10 cm. below the leaf joint +1 with the Pb-infections caused by natural infections in the field it is conspicuous that the former gives higher percentages of (Pb_2+Pb_3).

If we consider the ratio between the % (Pb_2+Pb_3) of P.O.J. 2878 and P.O.J. 3016 however then there is a fair agreement between the figures thus obtained : 1.99 (artificial inoculation) and 1.60 (natural infection, Sindanglaoet). The agreement with the ratios, calculated from the Pb-percentages of the variety trials is especially for the year 1939 not so good.

As the damage is chiefly caused by the Pb_2—and Pb_3—stadia and as the purpose of the resistance-trial is to compare the reaction of sugarcane varieties to infection with *Fusarium-pokkahboeng* with each other, in our opinion the artificial method of inoculation at 10 cm. below the leaf joint+1 will answer the purpose.

ACKNOWLEDGMENTS

We are much indebted to Mr. M. Halma for his valuable help in the lay-out of this trial and the mathematical treatment of the data.

SUMMARY

In a field trial (split-plot design) with 6 replications the reaction of the two main varieties P.O J. 2878 and P.O J. 3016 to injection with fusarium-conidia at an height of 10, 15 and 20 cm. below the leaf joint+1 was investigated.

The following conclusions were drawn :

1. The mean percentages of infection [% Pb-total and % (Pb_2+Pb_3)] caused by inoculation at 10, 15 and 20 cm. below the leaf joint +1 of the sugarcane varieties P.O.J. 2878 and P.O.J. 3016 were highly significant.

TABLE V

COMPARISON OF THE RATIOS OF % (Pb_2+Pb_3) OF P.O.J. 2878 AND P.O.J. 3016 BY ARTIFICIAL INOCULATION AT 10 CM. BELOW LEAF JOINT+1 AND BY NATURAL INFECTION

Sensitivity	Inoculation at 10 cm.		Variety-trials 1939		Variety-trials 1941		Sindanglaoet 1st count		Sindanglaoet 2nd count		Sindanglaoet 3rd count	
	P.O.J. 2878	P.O.J. 3016	P.O.J. 2878	P.O.J. 3016	P.O.J. 2878	P.O.J. 3016	P.O.J. 2878	P.O.J. 3016	P.O.J. 2878	P.O.J. 3016	P.O.J. 2878	P.O.J. 3016
% (Pb_2+Pb_3)	71.1	35.7	10.2	2.9	2.4	1.9	7.09	4.13	9.01	5.49	10.03	6.69
$\frac{\%\,(Pb_2+Pb_3)\text{ P.O.J. 2878}}{\%\,(Pb_2+Pb_3)\text{ P.O.J. 3016}}$	1.99		3.51		1.26		1.71		1.64		1.49	
							Mean : 1·60					

2. For testing the sensitivity [% (Pb_2+Pb_3)] inoculation at 10 cm. below the leaf joint +1 is recommended. Differences in susceptibility between P.O.J. 2878 and P.O.J. 3016 however could not be proved with this method of inoculation, but P.O.J. 2878 proved to be significantly (at the 1% point) more sensitive than P.O.J. 3016.
3. The percentages of Pb-infection caused by these artificial inoculation methods were higher than those caused by natural infection in the field at the sugar-plantation " Sindanglaoet " (Cheribon West-Java 1955) and in the variety-trials of the years 1939 and 1941.
4. There is a fair agreement between the ratios of the % (Pb_2+Pb_3) of P.O.J. 2878 and P.O.J. 3016 caused by inoculation at 10 cm. below the leaf joint+1 and the corresponding data of natural infection in the field on the sugar-plantation " Sindanglaoet " (1955).

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DISCUSSION

Mr. Rafay inquired whether in Java they had obtained *Cephalosporium* from *Fusarium* causing *Pokkahboeng*. The Chairman pointed out that it was a question of taxonomic confusion that existed due to the fact that different varieties of the same organism were involved in causing two different diseases. The wilt causing organism is *Fusarium moniliforme* var. *Subglutinans*, with *Giberella fujikori* as its perfect stage, whereas *Pokkahboeng* is caused by *Fusarium moniliforme* Scheld.

In the absence of the authors the following paper was presented by Dr. A. J. Mangelsdorf.

Paper

THE RESISTANCE OF SUGAR CANE VARIETIES TO THEIR MAJOR DISEASES[1]

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The control of diseases affecting commercial varieties of sugar cane throughout the world has been best accomplished by the use of resistant varieties. Many examples might be cited where large losses caused by disease have been reduced to a minimum by growing resistant varieties ; we refer particularly to the satisfactory control of such diseases as mosaic, Fiji disease, downy mildew, gumming, eye spot, red rot, sereh and *Pythium* root rot.

Many countries occupy an isolated position in relation to other sugar-producing countries of the world and maintain a rigid quarantine for the introduction of new varieties. These favourable geographic locations combined with quarantine have played a major part in preventing the introduction and spread of cane diseases from one place to another.

The degree of resistance to disease manifested by a sugar cane variety may be considered as a fixed genetic character of that variety. The reaction of varieties to disease is generally established by disease trials wherein the varieties being tested are either exposed to natural infection occurring under field conditions, or are inoculated with the causal entity of a specific disease. Such tests are conducted under field conditions where the environment favours the development and spread of the disease. Observations made under field conditions have also been used to determine varietal resistance to disease. Differences in varietal reaction to a disease are often noted, and may be explained either by environmental factors which favour the pathogen or predispose the variety to the disease, or by the development of different strains of the pathogen in the area where varietal reaction to disease is being determined. For example, the " loss " of varietal resistance to red rot disease is explained on the basis of new strains to which the varieties are not resistant. In Hawaii and elsewhere, the disease-resistant grading assigned to a variety is based on the results of disease trials combined with field observations.

During the past fifteen years or more, data gathered from the literature and from personal contacts and correspondence have been compiled on the resistance of the world's commercial and breeding cane varieties to the major cane diseases. It is our belief that such information would be of great assistance to all sugar cane pathologists and geneticists in controlling diseases through the development of resistant varieties, interchange of varieties, and collecting expeditions. It would be valuable also to universities and other scientific institutions.

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The system for recording the degree of varietal resistance to disease as developed by Martin in 1926 is used in this article for recording the reaction of varieties to disease. The tolerance of varieties to diseases is not considered in this paper. A variety may be resistant to a disease but not tolerant, and vice versa. Under some conditions susceptible varieties may be grown due to their tolerance to specific diseases. The symbols used for expressing disease resistance follow :

++	Very highly resistant
+	Highly resistant
=+	Moderately resistant
=	Average
=—	Moderately susceptible
—	Highly susceptible
— —	Very highly susceptible.

The symbol or abbreviation, shown below, and appearing in the tabulations under the symbol expressing disease resistance, designates the country which furnished the information regarding the reaction of each variety to each disease. In some instances, no reference to the country is given since such information was not available.

Arg = Argentina
A = Australia
Bar = Barbados
BG = British Guiana
BWI = British West Indies
Col = Colombia
Eg = Egypt
Fla = Florida
Fj = Fiji
For = Formosa
H = Hawaii
Ind = India
Jam = Jamaica
Jav = Java
La = Louisiana
M = Mauritius
Mex = Mexico
NSW = New South Wales
Pe = Peru
PI = The Philippines
PR = Puerto Rico
Q = Queensland
Re = Reunion
SAf = South Africa
Sam = Samoa

In compiling these data, it was necessary to translate different methods used for expressing resistance to disease into the "+ and — system" used in this paper. It is important, therefore, that corrections be made whenever possible by persons having authoritative information on varietal reaction to specific diseases.

The varieties considered in the following eight pages of tabulations were selected chiefly on the basis of their present commercial and/or breeding importance and are so indicatd by the letter (C) and/or (B) respectively. Varieties that were

Variety	Country	Status	Brown Spot	Brown Stripe	Chlorotic Streak	Downy Mildew	Eye Spot	Fiji Disease	Gumming	Leaf Scald	Leaf Scorch	Mosaic	Mottled Stripe	Pokkah Boeng	Pythium	Ratoon Stunting	Red Rot	Red Stripe	Rust	Sclerospora	Smut	Streak	Yellow Spot
Atlas	Q				+ NSW	++ A	– A	+ A	++ A	++ A		++ A					++ A						+ A
Badila	QF	C B		=+ H	=– A –– A	+ Fj + A	+ H	+ Sam =+ A	=+ A	=+ A		=+ A				=+ A	++ A	=– A			– Ind	=– SAf	+ A
B208	Q BWI	FC				– A		– A	– A			– A				– A	++ A	– A					+ A
B3439	BWI	C,B					=+ BWI		++ M			=– BWI											
B4098	BWI	C								+ BG		– BWI					=– M						
B4362	BWI	C			– BWI		= BWI		+ BWI	– BG		+ BWI	– BWI										
B34104	Col BWI	B,C	– PR		– BG – PR		– BWI		++ M + BWI	–– BG		– BWI –– Col											
B37161	BWI BG	C			+ BWI		+ BWI		++ M ++ BWI	=+ BG =– BWI		=– BWI – PR									=– M		
B37-172	BWI	C			– BWI		=– M		++ M			++ Jam	– BWI										
B40105	BWI									= BG		– BWI											
B41211	BWI	C							++ BWI			++ Bar											
B41227	BG BWI	C			=– BWI		= BWI		++ BWI	= BG =– BWI		+ BWI											
B43337	BWI											– Bar											
B43391	BWI	C										– Bar											
B44341	BWI											++ Bar											
BH10-12	BWI M,PR	B FC			– M		– M	=+ Sam = A	– PR	++ M		= PR = BWI – BWI		=– M	=– M		=+ For =– M				– M		
CP1165	Fla	B	++ Fla	+ Fla	+ La		+ Fla					++ Fla		+ Fla	+ Fla		– La	+ Fla					
CP27/108	La Fla	B	+ Fla	+ Fla			+ Fla					++ Fla ++ La		+ Fla	=+ La		=– La						
CP29-116	La Q	C	++ Fla	++ Fla	= A = La	++ A	++ Fla =+ A	=+ A = A	++ A + A	++ A	– For	++ A ++ La		++ La	++ La	=+ A	++ A ++ La	++ La			++ SAf		+ A
CP29-320	La	B,C	++ Fla	++ Fla	–– La	++ A	++ Fla	++ A				+ La		+ La	=– La		=– La	+ La			=– Arg		
CP30-24	La Fla	B	+ Fla	+ Fla			+ Fla					++ Fla ++ La		+ Fla			=– La						
CP33-224	La Fla	B	++ Fla	+ Fla	=– La		++ Fla					++ Fla ++ La		– La	+ La		++ La						
CP33-229	La Fla	B	++ Fla	+ Fla			++ Fla					++ Fla		+ Fla	=– La		++ La						
CP33-322	La Fla	B	+ Fla	+ Fla	+ La							=– La		=– La	=– La		+ La						
CP33-409	La Fla	B	++ Fla	++ Fla	+ La		++ Fla					=+ La		+ La	++ La		++ La						
CP34-79	Fla	B,C	++ Fla	++ Fla	– La	+ A	++ Fla	+ A				++ La		+ La	=+ La	– Fla	=– La						
CP34-120	La Fla	B,C	+ Fla	++ Fla	=– La		+ Fla	=– A	++ M			= La		+ La	++ La		– La	– La			++ SAf		
CP36-13	La	C	++ Fla	+ Fla	– For	+ A	++ Fla	+ A	++ M			++ La		+ La	= La		+ La =+ For	++ La					

Variety	Country	Status	Brown Spot	Brown Stripe	Chlorotic Streak	Downy Mildew	Eye Spot	Fiji Disease	Gumming	Leaf Scald	Leaf Scorch	Mosaic	Mottled Stripe	Pokkah Boeng	Pythium	Ratoon Stunting	Red Rot	Red Stripe	Rust	Sclerospora	Smut	Streak	Yellow Spot
CP36-105	La Fla	C B	− La	++ Fla	+ La		++ Fla	+ A	++ M			= La		++ La	+ La	− A − La	+ La	+ La					
CP38-34	La Fla	B	++ Fla	+ Fla			++ Fla					=− La			=− La		=− La						
CP43-47	La Fla	C B		+ Fla	+ La		+ Fla					+ La		+ La	= La		+ La						
CP43-64	La Fla	B	++ Fla	++ Fla			++ Fla					− La		=− La	=− La		++ La						
CP43-74	La Fla	B	+ Fla	+ Fla	+ La		=+ Fla					− La		+ La	=− La		+ La + Fla						
CP44-101	La	C	+ La	++ Fla	=+ La		++ Fla					=+ La		=− La	++ La	− La −− La	+ La	+ La					
CP44-154	La	C	=+ Fla	+ La	+ La							++ La		+ La	++ La	+ La	=+ La	+ La					
CP44-155	La	C B	++ Fla	++ Fla	+ La		+ Fla					+ La		=− La	=+ La		=+ La + Fla	+ La					
CP48-53	La Fla	B	++ Fla	+ Fla			+ Fla					++ La			++ La		− La						
CP48 126	La Fla	B	− La	+ Fla			++ Fla					=+ La			++ La		+ La						
Cato	Q	C				+ A			=+ A	=+ A						= A		= A					+ A
Chunnee	Ind Jav, H	B			+ La			+ A									+ Ind −− La						
Clark's Sdlg HQ426					= A	++ A		− A	− A	− A		− A				− A =+ A	++ A	++ A					= A
Co205	Ind	FC						= A															
Co 210	Ind	FC						++ A	+ A														
Co 213	Ind	B FC						++ Sam	+ A					− Ind			− Ind				− Ind		
Co 214	Ind	B										++ Ind											
Co 244	Ind							++ A															
Co 270	Arg Ind	C B				++ A		++ A	++ A	++ A		++ A									+ Arg		
Co 281	Arg, Ind Eg, La SAf	C B	− La	− Fla	+ La	++ A	− Fla	= A ++ NSW ++ Sam	++ NSW	++ A	=− For	− SAf − Col		+ La	− La	− La − SAf	− La = Fla =+ For	+ La			+ SAf − Arg − Ind	++ SAf	− A
Co 290	Arg, Ind Q, Re La SAf	C B	++ La	+ Fla	− For ++ A ++ La	=+ A	++ Fla	++ A ++ Sam	++ A	++ A	−− For	=+ A		+ La = Mex	++ La	=− A =+ A	− La, A − SAf − Fla =+ For − Ind −− A	=+ A			++ SAf ++ Arg − Ind		+ A
Co 300	Ind																				− Ind		
Co 301	Ind SAf	C				++ A		++ A				= A				=+ A	+ Ind − Fla				− SAf + Ind		− A

Variety	Country	Status	Brown Spot	Brown Stripe	Chlorotic Streak	Downy Mildew	Eye Spot	Fiji Disease	Gumming	Leaf Scald	Leaf Scorch	Mosaic	Mottled Stripe	Pokkah Boeng	Pythium	Ratoon Stunting	Red Rot	Red Stripe	Rust	Sclerospora	Smut	Streak	Yellow Spot
Co 312	Ind	C,B									— For	— Ind		— Ind			— A — Ind = Fla	— Ind			— Ind		
Co 313	Ind	C										— Ind		+ Ind			+ Ind				— Ind		
Co 331	Ind SAF	C															— Ind				=— SAf		
Co 352								++ A	++ A			++ A					=+ For						
Co 353					— For												=+ For						
Co 355					— For			++ A = NSW	++ NSW			=+ NSW					+ For						
Co 356						— A		++ A	++ NSW			++ NSW + Ind					=+ For				+ Ind		
Co 364								+ A															
Co 393												+ Ind					+ Ind						
Co 408																	+ Ind						
Co 411														+ Ind			+ Ind						
Co 413																	+ Ind				++ SAf		
Co 419	Col [illegible], Ind	C B				— A -- A -- For		-- A	+ A ++ M	— BG		++ Col — Ind					= Fla	— Ind			++ SAf + Ind		
Co 421	BG Ind	C B							++ NSW	++ A	-- For	+ Ind		= Mex			+ NSW	— Ind			+ Ind		
Co 440																	+ Ind						
Co 453	Ind	C										+ Ind					+ Ind	— Ind			+ Ind		
Co 475																			-- Ind				
Co 627																	+ Ind						
Co 631																	+ Ind				+ Ind		
Co 639																					+ Ind		
Co 641																					+ Ind		
Co 642																					+ Ind		
Co 645																					+ Ind		
Co 653																					+ Ind		
Co 655																					+ Ind		
Co 656																					+ Ind		
Comus	Q	C				++ A		= A	++ A	++ A		— A — Col				=+ A	++ A	++ A					= A
Crystalina	BG	FC							— PR														
D 1135	H,Q	FC		=— H	=+ H	= A	=+ H	-- Sem — A	= A =— NSW	++ A + H		= A =— NSW + H			+ H		++ A	++ A					+ A

Variety	Country	Status	Brown Spot	Brown Stripe	Chlorotic Streak	Downy Mildew	Eye Spot	Fiji Disease	Gumming	Leaf Scald	Leaf Scorch	Mosaic	Mottled Stripe	Pokkah Boeng	Pythium	Ratoon Stunting	Red Rot	Red Stripe	Rust	Sclerospora	Smut	Streak	Yellow Spot
D14-34	BG	C								-- BG													
D62-43										- BG													
D142-41										-- BG													
EK28	Q Jav	B FC			- A	=+ A		- A	- A	- A		=+ A				=+ A	++ A	++ A					
Erianthus		B						++ A															
Eros	Q	C			= A	-- A		=+ A = NSW	++ A	++ A						=- A =+ A	++ A - NSW	=+ A					= A =- A
31 Fla 436	Fla	C	++ Fla	++ Fla			++ Fla					++ Fla		+ Fla			= Fla + Fla	+ Fla					
31 Fla 962	Fla	C	++ Fla	++ Fla	=- La		++ Fla					+ Fla		+ Fla		- Fla	= Fla + Fla	+ Fla					
36 Fla. 819	Fla	C B	=+ Fla	++ Fla			++ Fla					++ Fla ++ La					=- La						
For 107	For				- For		= For																
For 108	For	C		+ For	- For		=+ For				+ For =+ For.	- For					- For =+ For						+ For
For 110	For			=- For	- For						- For	=- For					-- For						
For 113	For										++ For												
For 117	For										=+ For												
For 118	For										++ For												
For 132	For										- For												
For 134	For	C			- For						= For - For	=- For					+ For =+ For						- For
Glagah		B															- For				- Ind		
Glagah, Java		B															+ Ind				- Ind.		
H 109	H, F	FC		- H	=+ H	=- Fj	- H	- Sam -- A		= H		= H			+ H								
H8965	H	FC		=- H			=- H			=- H		= H			+ H								
(H) Kohola 202	H	FC		=+ H			=+ H			+ H		=- H											
(H) UD 1	H	FC		- H			- H	-- A	++ NSW			+ H = NSW											
(H) UD 50	H	FC					+ H	- Sam		=- H		+ H											
(H) 26Q2823	H	FC		=+ H			-- H	- Sam		+ H		+ H											
(H) 28-4291	H	FC		=+ A	++ H		+ H	=- Sam - A	+ A	- H		+ H			+ H								
(H) 31-1389	H	FC		- H	= H	+ A	++ H	-- Sam -- A	=- A	=+ H		++ H			+ H								
(H) 31-2484	H	FC		=+ H	=- H	+ A	- H	- A	+ A	++ H		+ H											

Variety	Country	Status	Brown Spot	Brown Stripe	Chlorotic Streak	Downy Mildew	Eye Spot	Fiji Disease	Gumming	Leaf Scald	Leaf Scorch	Mosaic	Mottled Stripe	Pokkah Boeng	Pythium	Ratoon Stunting	Red Rot	Red Stripe	Rust	Sclerospora	Smut	Streak	Yellow Spot
H31-2806	H	FC		=+ H	— H		= H	— Sam	+ A	+ H		++ H			+ H								
H32-1063	H	C		=+ H	=+ H		+ H	-- Sam -- A	+ A	+ H		++ H			+ H								
H32-3575	H	FC		=+ H	=+ H		+ H	— Sam =- A	— A	=+ H		+ H											
H32-6705	H	B				=- Fj		— Sam															
H32-8560	H	C B		=+ H	=- H	+ A ++ Fj ++ For	++ H	— Sam -- A	+ A	+ H	-- For	++ H =- PR			++ H		+ For						— For
H37-1933	Pl H, Pe	C B		+ H	= H	++ Fj + For	++ H	=+ Sam		+ H	-- Pl -- For	++ H			++ H		++ H						— For
H38-2915	H	C B		+ H		= Fj	++ H	-- Sam — Fj		++ H		++ H			++ H		++ H						
H39-3633	H	C B		+ H	= H	+ Fj	++ H	+ Sam		++ H		++ H			++ H		++ H						
H39-7028	H	C B		+ H		++ Fj	++ H	= Sam		++ H		++ H			++ H								
H44-3098	H	C B		+ H	= H	-- Fj — For	++ H	— Sam		+ H	— For -- For	++ H			++ H		++ H						— For
Hind's Special	Fla	B				++ A		++ A															
HQ 5								-- A	=- NSW			=+ NSW											
HQ 285	Q	FC						+ A	— A			— A											— A
HQ 409	Q	B FC				=+ A			+ A	=+ A							++ A	++ A					
Jason	NSW	FC			+ NSW	+ A		+ NSW	+ NSW	+ NSW		++ NSW											
Kassoer	Jav	B						-- A									— For =+ For						
Katha	Ind.	B						++ A															
Korpi	Q	B			— A	+ A		=+ A	++ A	=+ A		= A				— A	++ A	+ A					
Lahaina		B FC		— H			— H			— H		— H -- Col			-- H		-- For						
Loethers	Jav	B						+ A									— For						
Mahona		B FC				— A		=+ A	— A	-- A		=+ A											+ A
ML 318	M	B							++ M														
M11-43	M	B							++ M														
M13-18	M	B							=- M														
M23-16	M	B							=- M														
M27-16	M	B							=- M														
M35-17	M	B							++ M														
M63-39	M	C			— M	— A			++ M					— M									
M72-31	M	B			— M		=- M		=- M					=- M			— M						

Variety	Country	Status	Brown Spot	Brown Stripe	Chlorotic Streak	Downy Mildew	Eye Spot	Fiji Disease	Gumming	Leaf Scald	Leaf Scorch	Mosaic	Mottled Stripe	Pokkah Boeng	Pythium	Ratoon Stunting	Red Rot	Red Stripe	Rust	Sclerospora	Smut	Streak	Yellow Spot
M76-39	M	C			– M				++ M					=+ M									
M112-34	M	C				–– A			++ M	=+ M					= M		=+ M						
M129-16	M	B							=– M														
M129-43	M	B							++ M														
M134-32	M	C			– M	=+ A	++ M		++ M	++ M				=– M			=– M			=– M	++ M		
M165-38	M	C			– M	=– A								=– M			=– M						
M168-33	M	B							= M												=+ Id		
M171-30	M	C			– M				= M	= M				=– M			=– M				=– M		
M311-41	M	B							++ M														
M423-41	M	C			– M				++ M								= M				+ M		
Mayaguez M336	M PR	B C							++ M			=– PR											
Black Innes M189	Q							– A	–– NSW			– A											
M1900 Sdlg.	Q	B FC			–	++ A		– A	– A	=+ A		= A				– A	++ A	= A					= A
33MQ157	Q	B				=+ Fj		+ NSW															
N-Co291	SAf	B										– SAf					=+ SAf						
N-Co293	SAf	C B										– SAf					+ SAf						
N-Co310	SAf	C B	++ La ++ Fla	+ Fla	+ La = A	++ A	++ Fla	=+ A		++ A	=+ For = For – For	=– A + For – SAf				– A =– A	+ For =+ For – La				– Ind		
N-Co339	SAf	C B										– SAf					– SAf						
NG 16	Q							– A															
Erianthus 28 NG 7	H	B						++ A															
28 NG 49								–– A															
28 NG 101								++ A															
28 NG 201								–– A															
28 NG 251		B						++ A															
NM 200	SAf																				++ SAf		
NM 210	SAf																				++ SAf		
Oramboo	Q	B FC				+ A		=+ A	++ A =+ NSW	–– A		– A					++ A						+ A
Pindar	Q	C B			= A =– Fj	++ A =+ A		=– Fj + A	++ A	++ A – BG		=+ A				=– A =+ A							+ A
Pompey	Q F,	B FC			– A	=– A =– Fj		+ Fj	= A =– NSW	=– Fj = A		=+ F		=– Fj		– A		++ A					+ A
POJ36	Jav H, For	FC		=– H	= H		= H	++ A		++ H		++ H – A			+ H		–– For				– Arg		
POJ100	Jav	B FC			=– A	+ A		++ A	+ A			+ A				=– A	– For						
POJ213	Q	B FC	++ La	+ La	++ A	– A	+ Fla	+ A	+ A ++ M	++ A		– A		=– La	=+ La	=+ A	–– La =– For	++ A			=– Arg =– M		+ A

Variety	Country	Status	Brown Spot	Brown Stripe	Chlorotic Streak	Downy Mildew	Eye Spot	Fiji Disease	Gumming	Leaf Scald	Leaf Scorch	Mosaic	Mottled Stripe	Pokkah Boeng	Pythium	Ratoon Stunting	Red Rot	Red Stripe	Rust	Sclerospora	Smut	Streak	Yellow Spot
POJ 228												− A											
POJ 234	Jav Q	B FC	++ La	+ Fla	++ A ++ La	− A	++ Fla	++ A	=− A	++ A		− La − A		− La	− La		+ La	+ La			−− Arg		
POJ 979								++ A				+ A											
POJ 2364	Jav	B			=+ A			−− A				+ A				+ A							
POJ 2379								+ A															
POJ 2714	Jav	FC B				− A		−− A	− A	+ A		+ A				− A		−− A			++ Arg		
POJ 2722	Jav	FC						+ A				+ A					− For						
POJ 2725	Arg Fla For, Q, SAf	C B	++ Fla	+ Fla	+ For − A	+ A	− Fla =+ Fla	− A	++ A	++ A		++ A − For		=+ A	=+ La	=+ A − A	++ A = Fla	++ A			++ SAf	+ SAf	+ A − For
POJ 2727	Jav	FC				− A		−− A						=− M			−− For =+ For				++ SAf	++ SAf	
POJ 2747						− A		−− A		++ A													
POJ 2875	Jav	B		=+ For		= A		−− A	+ A			++ A				=							
POJ 2878		C B		=− H	− H − A;M − PR − BwI	− A	=− A =+ For =− M =− H	− Sam − A	++ A + M	+ Fj ++ H, A =− M ++ BG		++ H ++ A		=− Mex	+ H − M	− A	=+ A =+ For − M	−− A			+ SAf + Ind	++ SAf	± A
POJ 2883	For Pl	C B		− For	− For	− A	− For	−− Pl −− A	+ A		−− For	= For − For − Col					+ For		− For		++ Arg		− Pl
POJ 2940	Jav					− A		−− A									+ For						+ Pl
POJ 2960					− For			− A									++ For				++ SAf ++ Arg		
POJ 2967	Jav	C															=+ For		−− Pl				− Pl
POJ 3016	Jav	C B			− For			− Pl				= For − For					= For =+ For						+ Pl − For
PR 1000	PR	C										++ PR											
PT 43-52	For	C			− For −− For	−− For	+ For				= For + For	++ For					=− For =+ For						
Q 10		B			− A	=− A		=− A	+ A	=+ A		=− A											
Q 20					+ A			+ A															
Q 25	Q	FC				+ A		−− A	++ A			− A											± A
Q 27		B						++ A															
Q 28	Q	C			= A	+ A		++ A	++ A	++ A		=+ A −				−− A	=+ A	+ A					− A
Q 42	Q	C			+ A	++ A		=+ A = A	=+ A	++ A						− A	++ A						− A
Q 44	Q	C			=+ A	=+ A		++ A	++ A	− A −− A						=+ A	+ A	++ A					+ A

Variety	Country	Status	Brown Spot	Brown Stripe	Chlorotic Streak	Downy Mildew	Eye Spot	Fiji Disease	Gumming	Leaf Scald	Leaf Scorch	Mosaic	Mottled Stripe	Pokkah Boeng	Pythium	Ratoon Stunting	Red Rot	Red Stripe	Rust	Sclerospora	Smut	Streak	Yellow Spot
Q 45	Q	C				=+ A		− A	++ A			++ A				− A	++ A	++ A					= A
Q 47	Q	C			= A	+ A		+ A	++ A	++ A	− For	+ A				= A	++ A	++ A					+ A
Q 49	Q	C			− A	=+ A		= A	++ A			= A				=− A	= A	= A	−− Pl				= A
Q 50	Q	C			++ A	= A		= A	++ A	++ A	− For	= A				=+ A	− A	++ A					= A
Q 51	Q	C				=+ A		=+ A	++ A									− A					
Q 56	Q	C				=+ A																	
Q 813	Q	B FC			+ A	+ A		+ A	++ A	++ A		+ A				− A	+ A	++ A					+ A
RP 6	M	B FC							+ M	++ M							− M				=− M		
RP 8								−− A	++ M	− M											− M	−	
Ragnar	Q	C				+ A		++ NSW	++ NSW														+ A
SC 12-H	BWI	B FC						= A	= M	− A − M		− Col − Pl					− M						
SJ 2	Q	C				++ A			− A	−− A						=− A	+ A						+ A
SJ 4	Q	C			= A −− A	+ A			−− A	= A		= A				= A	+ A	=+ A					= A
SJ 16	Q	C				− A			=+ A							=− A		− A					+ A
S Spont Burma	Fla H Ind Jav	B						++ A															
S. Spont Tank		B						++ A															
Saretha	Ind	B						++ A															
Striped Tip	H	FC		=+ H			=+ H			=− H		− H											
Toledo	Pl	B						++ A															
Trojan	Q	C			− A = A − H	− A	− A = A	=+ Fj ++ A + A	++ A	− A	− For + For	− A				− A	++ A	++ A					− A
Turkistan Spont	Col Fla SAf	B	−− La		+ La							− La		+ La	+ La								
Uba	H SAf	B FC		=+ H			++ H	−− A		+ H	+ For	+ H			+ H							−− SAf	
Uba Marot	H M	B				−− Fj =+ A		++ A	++ M	++ M							+ M				+ M		
US 1694	Fla	B	+ La		+ La							++ La		+ La	+ La		−− La						
Vesta	A	C			− A	− A	= A	+ A =+ A	++ A	+ A		++ A				− A	= A =+ NSW	++ A					+ A
Vidar	Q A	C				=− A				=+ A						− A	=+ NSW						
Yel Caledonia (Malabar)	H, Re	FC		=− H	= H	= Fj	+ H	− Sam −− A =− Fj		=− H =− Fj		+ H ++ Col − NSW			+ H								

at one time of commercial importance are so indicated by (FC) indicating formerly commercial. Other varieties are also included where their reaction to disease was noted in the literature.

The value of listing varieties with their reaction to disease may be readily appreciated by referring to a few specific cases. The variety Lahaina, also known as Bourbon, Cana Blanca and Otaheite, was at one time the leading commercial variety in a number of countries ; but its susceptibility to root rot caused its replacement with resistant varieties. This variety is also highly susceptible to mosaic, leaf scald, gumming, eye spot and Fiji disease ; in other words, it possessed little or no resistance to the major diseases. The variety H 109 replaced Lahaina in Hawaii because of its resistance to root rot. However, H 109 was not resistant to such diseases as mosaic, leaf scald and eye spot. In recent years, 32-8560 replaced H 109, and more recently 37-1933, 44-3098 and other varieties, are replacing 32-8560. The varieties 32-8560 and 37-1933 are moderately to highly resistant to all the major diseases in Hawaii. A glance through the list shows that varieties such as Atlas, Q 813 and others, are resistant to most of the major diseases of the world.

No claims for completeness are made in this paper since certain data relative to varietal resistance were not available. The main references reviewed on varietal resistance to disease are appended. Information relative to varietal resistance furnished by the following members of the Standing Committee for the 1956 I.S.S.C.T. Congress on "Sugar Cane Diseases and their World Distribution" is also included : E.V. Abbott, B.A. Bourne, C. G. Hughes, T. T. Lo, G. Orian and P. E. Robinson. The writers very much appreciate having received this information, since it has helped to make the compilation of data more complete and useful to sugar cane geneticists and pathologists.

With more testing of varieties against disease as the result of the development of new commercial varieties, and the presence of new strains of a pathogen we recommended that the Standing Committee of the I.S.S.C.T. on " Sugar Cane Diseases and their World Distribution "assume the responsibility of maintaining current information on " The Resistance of Sugar Cane Varieties to Their Major Diseases."

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DISCUSSION

During the discussion, Mr. Rafay pointed out that contrary to the observation made in the paper, Co. 419 was found to be a susceptible variety in India.

In the absence of the author the following paper was taken as read.

Paper

OCCURRENCE OF A DISEASE SIMILAR TO RED STRIPE OF SUGARCANE IN MAURITIUS

G. Orian

Department of Agriculture, Mauritius

DISCOVERY OF THE DISEASE ON SUGAR CANE AND CERTAIN GRASSES

A severe outbreak of a disease with symptoms similar to those of red stripe was detected in December 1954 on the two varieties B. 3337 and B. 37161, on a small estate in an isolated and wooded elevated region of the island.

Cultivation of sugarcane in that locality had been discontinued for many years, but had been resumed in 1951, the area under cane on the estate being only about seventy-five acres, all cleared from secondary thicket. The varieties grown are M. 134/32 and some M. 423/41, Ebene 1/37, M. 165/38, B. 3337 and B. 37161. The diseased Barbados canes were six-months-old plant cane, grown from cuttings supplied by the Richelieu Experiment Station.

In as much as the disease was not known to occur at that station, nor indeed had its presence been previously reported in Mauritius, it was considered that such a localized outbreak could possibly be due to the existence of the disease on wild grasses on the estate. A survey of the field was consequently effected on December 24, 1954, with the specific object of looking for such hosts, and during the visit, two grasses, *Paspalum nutans* Lam. and *P. paniculatum* L. were detected in and around the field, with necrotic stripes on the leaves. The former grass was seen more frequently and more severely affected than the latter, and upon examination in the laboratory later, both were seen infected with a bacterial disease. Maize had been planted in the interrows of the Barbados canes, and one of the maize plants was later observed with a peculiar striping of some of the leaves.

Being pressed by time owing to forthcoming departure on leave prior to retirement, the writer concentrated on isolating the pathogen from the diseased sugar cane and *P. nutans* plants only and determining their relationship if any.

SYMPTOMS OF THE DISEASE ON SUGAR CANE

The disease is evidenced on the sugar cane by the presence of long, continuous stripes, dark-red in colour, often linear, but more frequently forming bands up to ¼ inch or more in width. Contiguous stripes may fuse together, forming still larger stripes on the leaves.

The stripes are more numerous towards the bottom part of the leaf ; they are of varying lengths, ending abruptly upwards somewhere along the length of the leaf, except those too near the edges, which end along the leaf margins. Some of

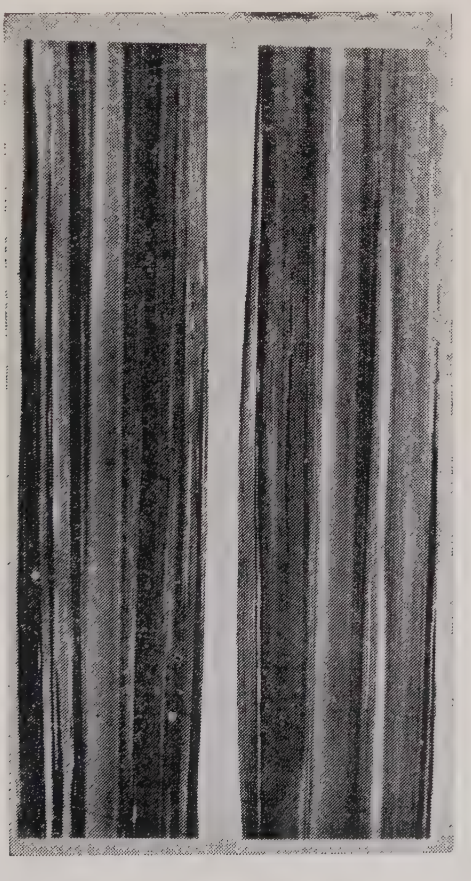

Fig. 1. Stripes on sugarcane leaves (Natural Infection)

the very fine streaks may be only a few inches long, also ending abruptly downwards.

When the red colour is not fully developed, as in the young stages of development, there is sometimes a narrow, light yellow border to the stripe. Very early, however, the red colour becomes fully developed, when the stripes have borders contrasting sharply with the adjoining green leaf tissue. They are sometimes continued upwards by a linear, light-yellow streak for a length of a few inches, in which red dots and short portions of red streaks occur. The stripes have not been seen to enter down into the sheath. Occasionally, small, thin patches of white, dried-out exudate are present along the stripes, chiefly on the under surface of the leaves. Rotting of the growing point has not been observed, but partial rotting of the heart leaves of the spindle was occasionally seen.

SYMPTOMS OF THE DISEASE ON *PASPALUM NUTANS*

On *P. nutans*, the stripes occur either along one edge or somewhere along the leaf blade and extend in general throughout the length of the leaf. They are

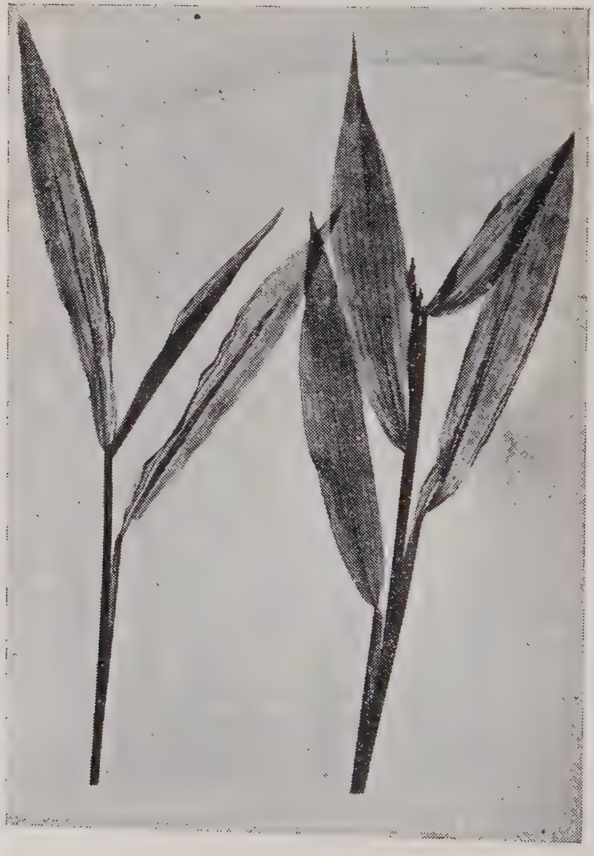

Fig. 2. Stripes on *Paspalum nutans* (Natural Infection)

water-soaked in the early stages, soon turning light to dark brown ; afterwards drying out of the affected tissues occurs. No red colour is developed. The stripes generally extend as brown bands down the sheath, and the disease is sufficiently virulent on the host to kill many of the affected shoots. Patches of thin, dry, white exudate may sometimes be seen on both surfaces of the diseased leaves when growing in the open, but this is best seen when inoculated plants are grown under shelter.

ISOLATION OF THE PATHOGEN AND SUMMARY OF THE INOCULATION WORK EFFECTED

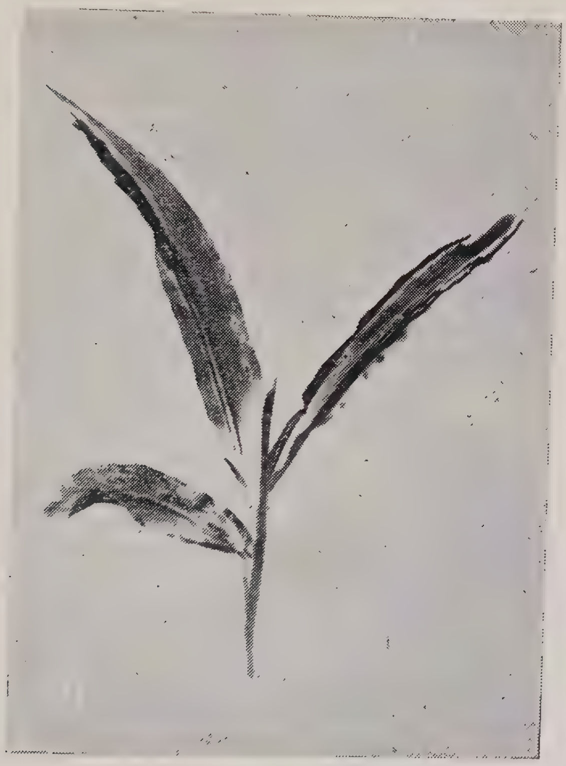

Fig. 3. Stripes on *Paspalum paniculatum*
(Natural Infection)

A number of pure cultures of the sugar cane pathogen were obtained in the laboratory, of which two were used for inoculation into sugar cane and the *P. nutans* grass. Of those obtained from *P. nutans*, two isolates were also selected and similarly used. These cultures were inoculated as follows :

(a) *Into sugar cane* : A suspension of each culture in sterile water was injected into a number of B. 3337 and B. 37161 shoots by means of a hypodermic syringe, the needle of which was thrust into the spindle about one inch below the top of the youngest visible leaf sheath, so as to reach the heart leaves.

(b) *Into P. nutans* : A drop of each suspension was placed on the sheath of the youngest expanded leaf of vigorously-growing *P. nutans* shoots, about half-an-inch below the ligule, and stabbed through a few times with a sterile needle.

All the inoculations developed on sugar cane the red stripes characteristic of the disease. Similarly on *P. nutans*, brown stripes as present on the grass in nature developed from the punctured leaves in all cases. Controls, in all the series of inoculations, remained healthy. The organisms were reisolated from the two hosts and upon inoculation into sugar cane yielded the symptoms of the disease.

The cultural characters of the pathogen have not been studied, but cultures have been forwarded to the Commonwealth Mycological Institute for favour of identification.

At the time of writing, exploratory work on the disease of *P. paniculatum* and on that of the maize plant found diseased in the affected field on the estate concerned, has given indications that both were due to the same pathogen.

DISCUSSION

The work described above has proved that the disease resembling red stripe discovered on sugar cane in December last in Mauritius, also exists on the grass *Paspalum nutans* Lam. and, most likely, also on *P. paniculatum* L. on the estate where the outbreak occurred.

Maize growing from seed, the presence of the disease suspected on the plant found affected, would be evidently due to passage from the sugar cane or from the wild grasses mentioned to the maize.

The Barbados canes in Mauritius were imported from Trinidad in 1945, and had been inspected before despatch in that country both in the nursery of the Department of Agriculture and in the laboratory.

Red stripe was not known to exist in the British West Indies in 1945, when the Barbados canes were forwarded to Mauritius. Referring to a letter from E.B. Martyn dated 1.3.52., J.P. Martin of Hawaii wrote to the writer on February 14 last, that symptoms of red stripe had, in 1952, been observed in Barbados, B. Guiana, and Trinidad, but that it was then, however, known that the disease had been present in Barbados for fifteen years or so.

There could, therefore, be possibility for one or a few of the Barbados cuttings imported in 1945, to have been infected with the disease in a mild form, which would have escaped attention at the time of their examination, as through ignorance of its existence in the area, it would not have been specially looked for.

No disease, however, was detected on these canes during their two-year period of quarantine after arrival in Mauritius, where they were under weekly observation by three responsible officers of the Department of Agriculture, namely, the Plant Pathologist, the Entomologist and the Plant Breeder. Neither was any disease observed on these canes in the experimental plots of the Department in the various parts of the island where they were subsequently grown for study. There seems to be little likelihood that such a spectacular disease as red stripe would have then completely escaped attention. For the disease to have been imported from Trinidad in 1945, it would be necessary to assume that it can be transmitted for a number of years successively, by cuttings from canes showing but very little signs of its presence. Yet J. P. Martin in his letter already referred to, states that transmission of red stripe by cuttings would be very rare.

The writer recollects having seen many years ago on an estate in Mauritius a very few cane shoots with a small number of stripes on the leaves resembling red stripe. The affected shoots were, however, so rare that he paid no attention to what then seemed insignificant markings. Several years later he again found some red stripes on a few cane shoots in another part of the island, but he then thought that the symptoms could be possibly the speical type of stripe which gumming disease sometimes produces. In presence of the outbreak of the disease reported in this study, he is of the opinion that it could be the same as that of which he found traces in the island in the past.

Again, after the discovery of the disease in December last, the Barbados varieties have been submitted to inspection at the Richelieu Experiment Station and in all the Demonstration plots cultivated by the Department of Agriculture in various parts of the island, without the disease being detected. It has, however, been recently reported on some of the Barbados varieties on three other estates in the island. Furthermore, a small outbreak of a disease resembling more mottled stripe than red stripe was detected on B. 37161 at the Central Experiment Station at Reduit in January 1955. Preliminary investigations by the Acting Plant Pathologist suggested to that officer that the disease at the Central Experiment Station could be the same as that mentioned in this report. The writer has not personally enquired into the matter. However, replying to a query by the writer, J. P. Martin wrote to him that the dark-red colour of red stripe usually remains as such but that they faded somewhat in very old leaves. He added that mottled stripe often produces symptoms very similar to red stripe but that the symptoms of the former fade more so than those of red stripe disease. It would, however, appear that the disease resembling red stripe in Mauritius, produces at times symptoms much resembling those of mottled stripe. To conclude, the writer must state that the origin and true nature of the disease discovered in Mauritius in December 1954 have still to be worked out as also must be worked out the role of the diseased grasses in the transmission of the disease.

SUMMARY

A disease with symptoms resembling those of red stripe was discovered in Mauritius in December 1954 on the Barbados canes 3337 and 37161. The outbreak occurred on a small isolated estate on which the cultivation of sugar cane had been recently resumed after having been discontinued for a very long period of years.

The disease was also detected on a wild grass, *Paspalum nutans* Lam. and its presence was suspected on another grass *P. paniculatum* L., both growing in and about the diseased field. A brief account is given of the experiments by which the identity of the disease on sugar cane and *P. nutans* was proved.

The Barbados canes were introduced in Mauritius from Trinidad in 1945 from material certified healthy. No disease had been observed on the imported canes during their two-year period of quarantine ; neither was any noted in the various parts of the island where the canes were grown, until the localized outbreaks in 1954 and 1955. The disease has, however, been recently found on some Barbados varieties at three other places in the island. Furthermore, a disease resembling more mottled stripe than red stripe was detected in January 1955 at the Central Experiment Station of the Department of Agriculture.

Through proceeding on leave prior to retirement, the writer was unable to study the problem more completely, but cultures of the pathogen isolated from the red stripe type of disease on sugar cane and from *P. nutans* had been forwarded to the Commonwealth Mycological Institute for identification. The origin and true nature of the disease in Mauritius, and the role of the diseased grasses in its transmission, have still to be worked out.

Mr. N. V. Mohan Rao then presented the following paper.

Paper

STUDIES ON SUGARCANE SMUT

N.V. Mohan Rao,

and

P. Prakasam

Sugarcane Research Station, Anakapalle

Plant diseases are known to have interfered with the prosperity of countries, often causing enormous losses in agricultural produce and sometimes causing even privation of people. The national calamity that befell European countries in 184os on account of the late blight of potato is well known. The United States Department of Agriculture estimated the losses on account of plant diseases at three billion dollars annually. In India, annual loss in wheat due to rust damage was estimated at 49 million rupees.

Andhra State is no exception in witnessing epidemics of plant diseases. To speak only of sugarcane diseases it may be said that red rot disease of sugarcane was the first to attract the attention of cane growers as well as scientists in the country. The disease occurred in an epiphytotic form in the beginning of this century and threatened the sugarcane industry with extinction. Then came the sugarcane smut which also appeared in an epiphytotic form in 1947 in Hospet area. The disease had to be controlled by enforcing Pests and Diseases Control Act. Though serious losses were caused on account of sugarcane diseases from time to time, intensive research on the diseases of sugarcane with a view to keep the diseases under check was not done. Losses on account of diseases were accepted but the extent to which losses occur was not known. The known methods of disease control viz., seed selection, fungicidal treatment, avoidance of ratoons as in the case of smut etc. go a great way in minimizing losses but there are limitations in the application of these methods and they do not meet the problem in its entirety. The IndianTariff Board, in its report for 1950, observed that the best method of overcoming pests and diseases is the use of pest and diseases resistant varieties of cane, the testing of which should be given due importance at the Sugarcane Research Stations. Studies were therefore undertaken to investigate into the various aspects of the diseases with the starting of a separate mycological unit in 1947 at the Sugarcane Research Station, Anakapalle. It is proposed to review briefly, in the following lines, some of the important studies made on sugarcane smut from 1947 onwards.

THE DISEASE SMUT

The disease is caused by a fungus, *Ustilago scitaminea Syd.* and is the most easily recognised of all sugarcane diseases. Diseased plants produce from their apex, long whip like black shoots varying in size from a few inches to several feet. The short ones are straight and the long ones are irregularly curved. In the earlier stages the whips are covered by a thin, white membrane which soon ruptures and exposes black dust consisting of the spores of the fungus. These spores are disseminated by wind and through other agencies and infect healthy cane plants. It may be mentioned here that a casual and approximate estimation of the number of spores produced by a single whip, showed that an average size whip could produce over 5,000 million spores all of which are potentially capable of infecting healthy sugarcane plants. Thus, only a few smut whips would be sufficient to infect the whole crop in a country if conditions exist for all the spores to survive and come in contact with host plants. This fact should convince cane growers of the importance of eliminating sources of infection viz., smut whips even if they are found in small numbers in the field.

SURVEY OF THE DISEASE

In order to gauge the magnitude of the problem, the important cane growing tracts of the Composite Madras State were surveyed to note the prevalence and the degree of prevalence of the disease. 403 fields in 205 villages selected from 15 taluks were surveyed and found that the disease is prevalent in most of the cane growing tracts in varying degrees of intensity. A summary of the results of the survey is furnished in Table I.

TABLE I

INCIDENCE OF SMUT IN THE VARIETIES GROWN (ON SHOOT BASIS)

Variety	Percentage of fields infected								
	Plant crop infection			1st Ratoon infection			2nd Ratoon infection		
	Above 30%	10% to 30%	Below 10%	Above 30%	10% to 30%	Below 10%	Above 30%	10% to 30%	Below 10%
Co. 419	Nil	2	98	4	11	85	3	39	58
Co. 527	„	Nil	100	Nil	Nil	100	Nil	Nil	100
Co. 421	„	4	96	„	12	88	„	100	Nil
Co. 542	„	Nil	100	Nil	Nil	100	„	Nil	100
Co. 281	„	20	80	„	20	80	—	—	—
Co. 349	„	Nil	100	„	Nil	100	—	—	—
P.O.J. 2878	„	„	100	„	„	100	—	—	—
Co. 413	„	„	100	—	—	—	—	—	—

N.B. :—Dashes denote that there are no observations for those crops.

Co. 419 which is one of the eight varieties under cultivation is the most important variety occupying about 90 percent of the area under cane cultivation. Co.527, another important variety is grown mostly in Bobbili and Vuyyuru factory areas. Other varieties occupy small areas in factory and gur areas. It will be seen from the results given above that the important variety, Co.419, is susceptible to the disease and that the incidence is seen to increase from plant crop to ratoon. In Co.527, the incidence of the disease is less than 10 percent. The incidence of the disease in Co. 419 and Co. 527, as seen from the survey, is consistent with the varietal resistance studies conducted on this station and reported elsewhere in this paper. The results of the survey also point out to the need to preserve the 'wonder' cane, Co. 419, from being over-run by the disease.

MODES OF CARRYOVER OF THE DISEASE

It is generally known that fungal diseases are transmitted through soil, air, irrigation water, seed material etc. But the relative importance of one or the other were not assessed. For the control of any disease, it is necessary that one should know the important mode of disease transmission. The disease incidence through soil, air, and irrigation water being found comparatively low the following types of seed material were tested for their degree of transmission.

1. Setts cut from smutted shoots.
2. Setts from apparently healthy canes of a smutted clump.

3. Setts from apparently healthy clump adjoining smutted clumps.
4. Stubbles from clump which threw out smut whips in the preceding season.

The percentages of smutted shoots resulting from the above types of seed material were 80, 1, 2, and 59 respectively. The risks involved in taking seed material from smutted shooots and from ratoon crops are at once evident from these figures. Setts from smutted shoots not only give rise to a high percentage of smutted shoots but they are also unsuitable as seed material since the buds are ill developed. Setts from the other two types of seed material viz. apparently healthy canes of smutted clumps and canes from healthy clumps adjoining smutted clumps gave rise to low percentage of smut. But even a low percent of smut will prove to be a potential danger if allowed to go unchecked. As pointed out earlier in this paper, a few smut whips would be sufficient to do the job.

VARIETAL RESISTANCE STUDIES

New varieties are being received year after year and they are tested for their suitability for introduction into the cane tracts of the State. The varieties are tested for their yield and other desirable agronomical characters. It was found necessary to test these new varieties simultaneously for their resistance to smut so that a variety even though very good agronomically but susceptible to smut is not allowed to spread in a locality. This is of utmost importance because if a good variety is released for cultivation by ryots, and if that variety is later found to be badly susceptible to smut, then it would be very difficult to withdraw that variety from cultivation before serious setback is caused to industry. That has been the experience of people in Uttar Pradesh and Bihar where, when red rot was raging in an epidemic form, and when promising varieties suddenly succumbed, it became a difficult thing to withdraw those varieties from cultivation. Having thus seen the utility of varietal resistance studies, all the agronomically important varieties were tested for their resistance to smut. The results of the studies are furnished in Table II.

The varieties reported in Table II are generally tested for three consecutive years to make sure of consistency in their reaction to smut. Of the standard varieties under cultivation in the State viz., Co. 419, Co. 449 and Co.527, Co. 419 is susceptible to the disease while Co. 449 and Co. 527 generally recorded less than 10 percent infection and are considered resistant to the disease. Since Co. 419 is the dominant variety in the State, occupying a large area, it is necessary to have a careful watch to see that this variety does not fall a prey to the disease. While Co.449 is grown in small areas, Co.527 is occupying entire factory area in Vuyyuru. It is gratifying to note from the crop of Co.527 at Vuyyuru that this variety is almost free from smut. Thus it is seen that the experimental results obtained at Sugarcane Research Station, Anakapalle, are consistent with the observations in the field.

Further, varieties Co.475 and Co.620 which are agronomically very good varieties were found very susceptible to this disease. Co.475 was observed to be susceptible to smut in BombayState also. If these varieties were not declared as

TABLE II

PERCENTAGE OF SMUT INCIDENCE IN VARIETIES TESTED (AVERAGE OF 3 YEARS)

S. No.	Variety	Percentage infection (clumps)	S. No.	Variety	Percentage infection (clumps)
1	Co. 213	46	21	Co. 650	11
2	Co. 281	9	22	Co. 659	Nil
3	Co. 349	37	23	Co. 672	52
4	Co. 419	36	24	Co. 673	37
5	Co. 421	18	25	Co. 677	48
6	Co. 449	11	26	Co. 681	72
7	Co. 467	22	27	Co. 682	10
8	Co. 471	18	28	Co. 684	10
9	Co. 475	55	29	Co. 719	3
10	Co. 527	3	30	Co. 722	40
11	Co. 615	19	31	Co. 727	Nil
12	Co. 617	17	32	Co. 729	2
13	Co. 620	57	33	Co. 731	31
14	Co. 624	14	34	Co. 732	47
15	Co. 627	57	35	Co. 733	11
16	Co. 630	3	36	Co. 734	28
17	Co. 632	36	37	Co. 744	1
18	Co. 633	30	38	Co. 849	Nil
19	Co. 646	36	39	B. 208	14
20	Co. 647	29	40	P.O.J. 2878	6

susceptible they would have gone into cultivation only to be taken hold of by the disease at a later date. It may thus be said that the varietal resistance studies have helped in preventing great losses to cane growers.

LOSS DUE TO SMUT

As already stated, diseased plants produce smut whips from their growing points. These smutted shoots do not ordinarily develop into millable canes.

Clumps which get diseased early in the season, produce thin and grassy shoots and none of those shoots develop into millable canes. Such clumps are generally more in [ratoon crops due to primary infection present in the stubble. Certain other clumps which become diseased later on in the season escape total destruction which means while a few shoots develop into millable canes, a few others become smutted. Thus it is obvious that the disease causes loss of millable canes both when the disease occurs early in the season and late in the season. Though it is evident that there is loss of millable cane, how much is that loss is not known. The disease incidence is usually expressed as percentage of shoots or clumps affected. But it is clear that percentage incidence is not same as percentage loss. If the loss is known quantitatively, a cane grower would take serious note of the disease with a view to avoid it. Studies were, therefore, conducted at this research station to evaluate the probable loss in yield on account of this disease.

The study was on clump basis where a sufficiently large number of smutted clumps were marked from the time of smut manifestation, and the progress of the disease from time to time was recorded for each clump. At harvest time the clumps were harvested separately and the weight of the clumps and the various yield attributes were recorded. Similarly a large number of healthy clumps were studied and compared. A summary of results obtained during the last three years is furnished below :—

TABLE III

LOSS AS REFLECTED BY THE YIELD ATTRIBUTES

Particulars	Loss as percent on control (Healthy clumps)				
	Plant crop			Ratoon crop	
	1951-52	1952-53	1953-54	1952-53	1953-54
Mean number of canes per clump	23.67	46.15	48.09	43.35	70.40
Mean weight of millable canes per clump in lbs	39.08	55.65	52.34	51.32	73.48
Average length of cane in inches	13.16	9.98	5.30*	14.46	4.57*
Average number of internodes per cane	12.16	6.81	0.19*	10.44	3.43*
Average diameter of cane in cms	9.13	3.80*	4.60*	8.00	3.38
Average weight of single cane	20.00	16.82	8.23*	11.11	9.95*

* Not statistically significant.

It is evident from the data that a smutted clump suffers definite loss in weight of millable canes when compared with a healthy clump. In plant crop, the average loss in a smutted clump ranged from 39.08 to 55.65 percent of the weight of healthy clump during three years while in ratoon crop the loss ranged from 51.52 to 73.48 percent. The data have further revealed that the loss in a smutted clump is not only due to the fewer number of canes produced but also due to those canes being inferior to the canes from a healthy clump in respect of yield attributes. All the differences between the healthy and smutted clumps in respect of the various yield attributes, except those marked with an asterisk, are statistically significant. Having determined the average loss that a smutted clump suffers, it will be possible to estimate the loss of millable canes in a field when the number or percentage of smutted clumps in a field is known.

LOSS IN RELATION TO TIME OF INCIDENCE

As it has been the case with most of the fungus diseases, the age of the crop at which the disease occurs has a great influence on the extent of loss. A large number of clumps which got smutted at early age of the crop died completely while clumps which got smutted late in the season escaped total destruction. The following Table bears out the above point.

TABLE IV

TOTAL LOSS IN RELATION TO TIME OF DISEASE OCCURRENCE

Age of crop in months	Percentage of clumps totally smutted to number of clumps smutted	
	1951-52	1952-53
2	28.6 (June)	36.0 (May)
3	15.7 (July)	27.1 (June)
4	5.6 (August)	26.4 (July)
5	Nil (September)	9.2 (August)
6	6.5 (October)	—
7	3.4 (November)	—

It will be seen from the data furnished above, that while complete death of clumps are more when the incidence occurs at the early age of crop, they are even more if smut occurs at early age and in the earlier months of the year.

JUICE QUALITY OF CANES FROM SMUTTED CLUMPS

Though the healthy canes from smutted clumps are quantitatively inferior to canes from healthy clumps as seen in the preceding lines, they are normal for all outward appearance. But there is a strong belief that smut causes depression in juice quality. Canes from smutted clumps were, therefore, subjected to chemical analysis and compared with canes from healthy clumps. In the first two years the results were erratic. In the third year the results showed that canes from smutted clumps are slightly inferior in quality to canes from healthy clumps. But during all these years only composite samples, numbering two or three in each of healthy and smutted, were analysed. In the fourth year the smutted clumps were put to rigorous test in which 24 samples of canes from smutted clumps and 24 samples of canes from healthy clumps were crushed separately and juices analysed. The results of juice analysis are furnished in the following Table.

TABLE V

CHEMICAL ANALYSIS OF JUICES

Particulars	Sucrose %		Purity %	
	Healthy clumps	Smutted clumps	Healthy clumps	Smutted clumps
Mean values for 24 samples	17.29	15.42	89.40	85.36

Sucrose :—

Mean 17.29 and 15.42

S. E. of difference. $\sqrt{.3961} = 0.629$

$$t = \frac{1.87}{0.629} = 2.97$$

t (46) at $P = 0.05 = 2.014$

The differences are significant.

Purity :—

Mean 89.40 and 85.36

S. E. of difference $\sqrt{3.9612} = 1.990$

$$t = \frac{4.04}{1.09} = 2.03$$

t (46) at $P = 0.05 = 2.014$.

The differences are significant.

From the above analysis, it is clear that the juices of healthy canes from smutted clumps are definitely inferior in quality to those of canes from healthy clumps. The statistical examination of juice quality having been done only once, it will be continued in future years to verify the results obtained during this year. If these results are confirmed, it may be said that the loss on account of smut is two fold viz., quantitative and qualitative which means both the cane growers and the sugar factory-owners would be losers.

Certain preliminary studies which were carried out during the course of the main investigations are briefly reported hereunder.

PHYSIOLOGICAL RACES IN SMUT

As sugarcane is grown in most of the districts eparated by long distances, it was considered necessary to see whether in any particular region a more virulent strain of the fungus is in prevalence so that necessary quarantine measures could be taken to prevent that strain from spreading into areas where less virulent strains of the fungus are in prevalence. Smut spores from important cane centres were collected and tested along with the local strain in pot experiments. The results showed that the regional isolates did not differ from one another either morphologically or in virulence indicating thereby that there are no physiological races in the sugarcane smut occurring in this State.

SUSCEPTIBILITY OF BUDS FROM DIFFERENT PORTIONS OF CANE

During the course of studies on smut, it was noticed that where buds from mature portions of cane were planted, there was not only poor germination but also low percentage of infection. So buds from different portions of cane viz., underground, bottom and top, as well as buds from short crop (6 months old crop) were tested for their receptiveness to smut infection. It is seen from the results that buds from immature portions of cane and those from underground portions are highly susceptible. In the varietal resistance studies, therefore, uniformly immature setts were selected for all varieties under test.

SUMMARY

(1) The importance of plant diseases as affecting the prosperity of countries, the occurrence of epiphytotics in the Andhra State, and the scope of research on the important disease of sugarcane are discussed.

(2) The disease, smut, is briefly described and the approximate number of spores produced by a whip is indicated.

(3) A survey of the disease in the important tracts of the State showed that the disease is prevalent in most of the sugarcane tracts in varying degrees of intensity. Of the eight varieties in cultivation, Co. 419 recorded high incidence of smut, the incidence generally increasing in ratoons.

(4) Studies on mode of carryover of the disease showed that stubbles of smutted clumps and setts from smutted shoots gave rise to a high incidence of smut while setts from healthy canes in the smutted clumps and setts from healthy clumps in the proximity of smutted clumps gave rise to a low incidence of smut.

(5) The practical utility of varietal resistance studies is discussed and the reaction of the varieties to smut is given.

(6) Loss in yield due to smut was estimated. A smutted clump is found to suffer definite loss in weight when compared with a healthy clump. The loss in weight of smutted clump is not only due to fewer number of canes produced but also due to those canes being inferior in respect of yield attributes. The loss in

weight of a smutted clump is greatly influenced by the age of the crop at which incidence occurs, earlier incidence causing greater loss.

(7) The juice quality of canes from smutted clumps was found to be inferior.

(8) Smut spores from different localities of the State were tested and found that there appeared to be no physiological races of smut occurring in this State.

(9) Immature buds and buds from the underground portion were found more receptive to smut infection than mature buds.

ACKNOWLEDGMENT

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DISCUSSION

During the discussion, Mr. Kirtikar pointed out that in the paper presented, setts from smutted canes had given less infection as compared to those from healthy canes growing in the vicinity of smutted ones. Mr. Mohan Rao explained that the infection percentage was too low to draw any conclusion. In reply to a further question from Mr. Kirtikar, Mr. Rao explained that although Co. 419 and Co. 475 were highly susceptible to smut, these were being recommended for cultivation in view of their superior yield and agronomic qualities. He further added that these varieties could be kept free of smut by systematic roguing.

Mr. Sharma pointed out that the canes from smutted clumps were more fibrous and the extraction was poorer. This fact should also be taken into consideration in assessing the losses. Mr. Rafay remarked that in North India, where majority of the cane varieties tested so far were susceptible, change of variety would not be helpful. Moreover, the old view that thick canes were less susceptible to infection had to be changed.

In the absence of the author the following paper was presented by Dr. E.V. Abbott.

Paper

THE RATOON STUNTING DISEASE OF SUGAR CANE IN LOUISIANA WITH NOTES ON ITS CONTROL

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INTRODUCTION

The first indication that a specific stunting factor may exist in sugarcane was obtained in Australia in 1944-45 (10). That the Australian pathologists could mechanically transmit the factor from sugarcane to sugarcane under controlled conditions was revealed in 1949 by Mungomery (8). In that publication the term "Ratoon Stunting Disease" was first used to indicate the diseased condition and since then it has apparently become established as the generally accepted name for the disease. Although the inclusion of term "ratoon" may prove to have been unwise, since it implies that the trouble affects only ratoon crops ; nevertheless, it may be accepted as referring to all transmissible growth retarding phenomena which occur in sugarcane but which lack any well defined diagnostic symptoms in that plant.

Based on field observations in Louisiana and the Australian literature, Abbott instituted investigations at the U.S. Sugarcane Field Station, Houma, Louisiana in 1951 to ascertain whether the disease was present there, and he reported in 1953 (1) the occurrence of a very similar disorder. In Louisiana the non-specific symptoms of the disease appear to be similar to those reported in Australia (10). In general these are : retarded growth of the plant accompanied by a deficient root system, slender shortened stalks which lack any readily apparent shortening of the internodes, reduced number of stalks per stool, and a very slight chlorosis of the leaves under unfavourable growing conditions (1). The orange-red nodal discoloration described in Australia (10) (11) has also been noted in Louisiana (1).

The probability that ratoon stunting disease may prove to be of basic importance in explaining the occurrence of a progressive yield decline, or "varietal deterioration" in vegetatively propagated sugarcane, has not been overlooked (2) (3). It is likely that a synergistic relationship between the stunting factor and other components of the sugarcane environment may exist. That such may be the case with regard to drouth effect has already been demonstrated (1) (11).

DIAGNOSIS

As yet there is no way by which the presence or absence of the stunting disease can be positively ascertained in individual stalks of sugarcane under field conditions in Louisiana. Nodal discoloration in Louisiana is often faint or variable ; red rot infection, borer damage, and much non-specific reddening of vascular bundles mask such discoloration in many cases. In Southern Florida, however, where sugarcane is grown on muck soil, nodal discoloration is more intense and more easily recognised.

The results of an attempt to obtain experimental evidence of the relationship of nodal discoloration to presence of the disease are in Table I. The seed cuttings used were from plants grown in the greenhouse from cane treated with hot water at 50°C. for 2 hours. While it is possible that escapes may have occurred due to inadequacy of the heat treatment, or that the methods of inoculation were not 100 percent effective, the results indicate, that there may be some doubt as to the reliance that can be placed on the presence of nodal-discoloration in diagnosing the disease.

TABLE I

OCCURRENCE OF NODAL DISCOLORATION IN MATURE STALKS OF 5 PLANTS EACH OF 2 VARIETIES OF SUGARCANE FOLLOWING DIFFERENT METHODS OF INOCULATION OF SEED CUTTINGS IN THE GREENHOUSE

Treatment	Number of plants showing nodal discoloration	
	C.P. 44/101	Q. 28
Control (not inoculated)	0	2
Inoculated with infective juice from C.P. 44/101.		
Cut ends of seed pieces dipped in juice	5	4
Juice injected with pressure punch[1]	3	5
Juice introduced in small hole with dropper	3	3
Sterile water injected with pressure punch[1]	2	1

[1] The pressure punch was a modification of that described by LeBeau (7). It consisted of a hypodermic needle with enlarged opening mounted on a 1-gallon pressure sprayer.

Inoculation experiments designed to discover local lesion, or systemic symptom producing hosts, are in progress. Inoculation by leaf rubbing with or without abrasives, and stem puncturing of a large number of different plants have yielded negative data. Chemical tests and protein analysis are in progress but we are still confronted with the dilemma of having to work with a real disease, the effect of which can be measured to some extent in large populations, but the presence of which must be doubted in any given case because of the lack of a specific diagnostic symptom or method of identification.

Field observations based on variation in growth of sugarcane in Louisiana have resulted in the assumption that one of our most promising varieties, C. P. 44/101, had not as yet become completely overrun by the disease. Thus, it was possible to select apparently healthy seed pieces from vigorous stools as well as apparently diseased seed pieces from noticeably stunted stools for our preliminary yield trials. The results in Table II show the reduction in yield obtained by inoculating the apparently healthy vigorous stalks with juice from stunted stalks of C.P. 44/101.

TABLE II

EFFECT OF RATOON STUNTING DISEASE ON YIELD OF C. P. 44/101 IN LOUISIANA. AVERAGE OF 4-1/100-ACRE PLOTS

Source of Seed Cane	Plant Cane 1953 Tons per acre	Plant Cane 1953 Reduction by disease Percent	Plant Cane 1954 Tons[2] per acre	Plant Cane 1954 Reduction by disease Percent	1st Stubble 1954 Tons per acre	1st Stubble 1954 Reduction by disease Percent
Selected Healthy[1]	41.5		33.2		46.5	
Selected Healthy-inoculated with juice of stunted cane	36.7	11.5	22.2	33.1	29.6	36.3
Selected Diseased-cane showing obvious stunting			27.8	16.3		
Selected Diseased-HWT at 50° C. for 2 hours			31.2	6.0		

1. Apparently healthy plants were selected in the field. These plants were the progeny of those originally selected as disease free in 1951. Seed for the inoculated treatment was from the same source.

2. L.S.D. .05=3.87 tons.

The yield from the hot water treated seed pieces would in all probability have been greater if the direct effect of hot water treatment (see discussion of heat treatment) on stand could have been eliminated. Although the yield differences in this experiment cannot be taken as an exact measure of the effect of ratoon stunting disease on yield under Louisiana conditions, they are indicative of extensive damage by the disease, and are sufficient to justify instituting a practical control programme.

EFFECT ON STAND

That the disease may have an adverse effect upon the number of primary shoots produced from planted cane may be seen from the stand counts in Table III taken from one of the variety yield trials at the Houma station. The "healthy" seed cane for this experiment was obtained from cane produced from hot water treated seed pieces. Thus, the effect of the heat treatment itself upon stand had been eliminated.

That the reduction in stands may not be wholly a result of lack of germination of the lateral buds was demonstrated several times in a number of greenhouse yield trials, as well as by observing germination in warm moist incubating chambers. In many cases the lateral buds of infected seed pieces were swollen and had actually grown an inch or more in length, but failed to continue growing and finally succumbed to the rotting action of micro organisms.

TABLE III

EFFECT OF RATOON STUNTING DISEASE ON STANDS OF 10 VARIETIES OF SUGARCANE PLANTED IN SEPTEMBER 1954 WITH THREE SOURCES OF SEED

Variety	Average No. of shoots per plot in 4-1/100-acre plots					
	A. Healthy (progeny of heat-treated seed)		B. Healthy inoculated with juice of RSD infected C.P. 44/101		C. "Field run-(RSD infected)-not heat treated not inoculated	
	Nov. 1954	May 1955	Nov. 1954	May 1955	Nov. 1954	May 1955
Co. 281	84	191	79	169	50	116
Co. 290	112	358	107	285	73	239
N. Co. 310	87	248	76	199	76	227
C. P. 29/116	104	197	89	55	81	182
„ 29/320	72	139	65	127	41	105
„ 34/120	69	189	77	148	50	130
„ 36/105	84	263	65	180	52	163
„ 43/47	89	246	101	187	68	163
„ 44/101	119	235	121	207	90	220
„ 44/155	84	241	90	220	65	177
Ave. of all varieties	90	231	87	178	65	172
% of "A"	100	100	97	77	72	74

HEAT TREATMENT

The control of the disease in Louisiana is the main objective of the research work in progress, and it is apparent that heat therapy is the only immediate means available. That heat therapy of sugarcane seed pieces infected with ratoon stunting disease has resulted in obviously increased yields has been amply demonstrated by the Australian investigators (9) (11). Following the valuable work performed in Australia as a guide, our investigation into the control of the disease has been based on the use of hot water at 50°C. for 2 hours, or 52°C. for 1½ hours, or hot air at 54°C. for 8 hours (5). These treatments are very close to the thermal death point of most varieties of sugarcane (10). There is still more than just a remote possibility that there may be variants of the causal agent that differ in symptom-producing ability and tolerance to heat treatment of an order sufficiently high as to be unaffected by temperatures that would kill the cane. However, it now appears certain that the Louisiana sugar industry is in the process of adopting a control programme based on heat therapy not unlike that now in progress in Australia.

The demand for an early recommendation for the control of ratoon stunting disease on the part of the sugar cane growers of Louisiana has necessitated relying upon the results of heat treatment trials performed in Australia as a basis for experimentation and recommendation. As a working hypothesis it has been necessary to assume that those treatments found effective in eradicating the disease in sugarcane setts in Australia would also be effective here. This is necessary because although experiments are in progress which were designed to show differences in yield due to curative heat treatment (for example see Table II), they are of little value in detecting a low percentage of escapes if any have occurred. In addition the manifestation of the disease in Louisiana is not nearly as obvious as it is reported to be in Q. 28 in Australia. Whether the difference is of an environmental nature or in the stunting factor itself is not yet known. Thus, it was decided that the use of hot water at 50°C. for 2 hours, or at 52°C. for 1½ hours, and hot air at 54°C. for 8 hours, would be the base treatments for research. Most of the commercial and promising unreleased varieties were included in these treatments. The main objective in testing these heat treatments was to determine if one of them possessed any outstanding qualities over the others which would recommend it as a general curative treatment under Louisiana conditions.

The hot-water-treating tanks used were of sufficient size to contain a large excess of water volume to that of cane volume under treatment. Circulation was vigorous and temperature control was accurate to within ±½°C. of 50.5°C. The hot air oven used was of a special design which allowed warm air to flow rapidly around shallow layers of cane. The treating chamber of the oven was 4 feet high, 3 feet wide, and 8 feet long. Cane was so stacked that no large areas in the oven were void of cane. Since thorough and rapid circulation of air proved to be necessary, the oven was designed with this in view. After the average temperature within the oven reached the desired maximum (usually 54°C.), the variation between any one location and any other in the unit was not more than 2°C.

Although differences between varieties in their response to heat treatment were noted, definite trends as to the effect of any one treatment on all varieties were observed. The use of water at 52°C. for 1½ hours reduced stand counts in the field when compared to the non-treated controls more than 50 percent in practically all cases. Stand counts were reduced to zero at times. Hot water at 50°C. for 2 hours also reduced stands, but seldom to as great an extent as at 52°C. for 1½ hours. The hot-air treatments at 54°C. for 8 hours gave better stands than the hot-water treatment of 50°C. for 2 hours. In practically all instances the seed pieces subjected to the hot-air treatment either equalled or surpassed the controls in stand counts when the experimentalov en at the Houma station was used. In addition, the hot-water treatments in general caused the lateral buds of treated seed pieces to become soft, tender, and easily damaged even under careful handling. As a result a further reduction in stand counts could be expected. On the other hand the hot-air reatment usually caused a moisture loss of 10 percent in the treated seed pieces which resulted in a comparatively dry, tough stalk that was less likely to be injured in handling. The planting season in Louisiana occurs while the sugarcane stalks are still relatively young and succulent. Thus, it seemed that the use of hot air was to be preferred as a practical curative treatment for ratoon stunting disease here, and this has been borne out by experiments. It is apparent that the use of the hot-air treatment in Louisiana will be adopted by many of the growers (4) (5) (6) However, the technical problems involved in using hot air are very complex. The difficulty of securing uniform temperatures within the treating chamber is only one of the problems.

Because of the variation in air temperature that is expected in large hot-air ovens, the use of thermocouples to periodically check the internal stalk temperatures while under treatment has become standard practice in research in Louisiana.

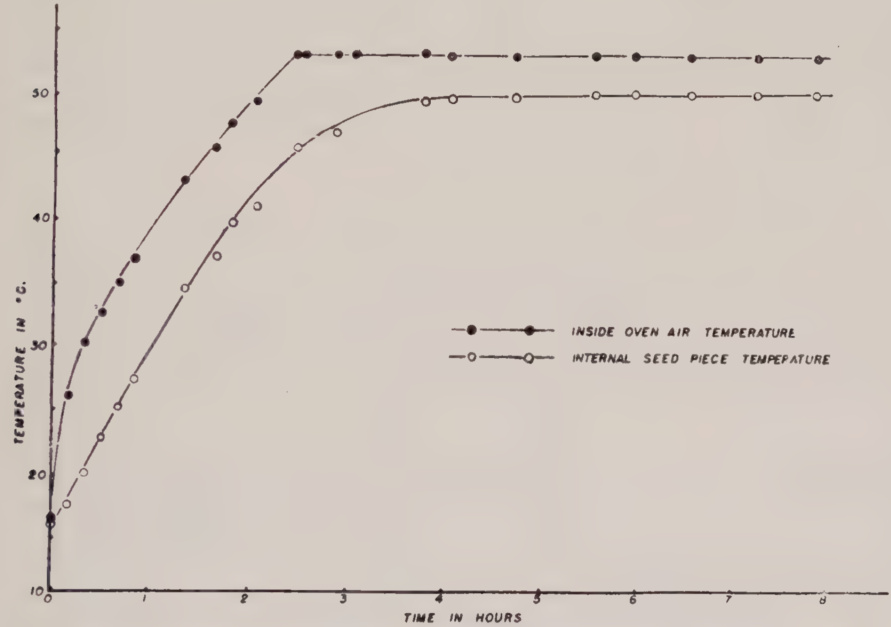

FIG. I COMPARATIVE TEMPERATURE READINGS INSIDE AND OUTSIDE OF A SUGARCANE SEED PIECE DURING A TYPICAL HEAT TREATMENT TEST RUN

Figure I shows the type of data collected using thermocouples at one position within the oven. One thermocouple of a pair was placed in the centre of a stalk having a diameter of 26 mm and the other was placed in close proximity to the stalk in the air stream. By establishing as many such locations as desired within the treating chamber and then executing several trial treatments, a rather complete picture is obtained of the performance of the unit. Flaws in oven design are easily spotted, and corrective procedures undertaken. That data on internal stalk temperatures taken at regular intervals throughout the treating period proved to be a better index of oven performance than air temperature data soon became evident. However, because variation does occur within an oven and between ovens of different designs, it is necessary that minimum and maximum allowable deviations be established that would apply to every oven used for heat therapy of sugarcane. At present in Louisiana such restrictions can be determined by inference and association only since there is no method as yet available for determining the degree of control achieved by heat treatment. This difficulty can be circumvented to some degree if the Louisiana industry will adopt those ovens for general use which have been tested and found to closely approach an ideal in rate of temperature rise and uniformity of heating. The Houma station oven, designed to be relatively inexpensive to construct and operate and which appears to be as proficient as any other, is shown schematically in Figure 2.

The following operational data were obtained : air temperature approached 54°C. ± 1°C. in 3 hours operation ; internal temperature of stalks 26mm in diameter reached a maximum of 50 to 52°C. in 6 hours, and these temperatures were maintained for the remainder of the 8 hours. Since little reduction in stand is experienced by treatment at higher temperature, it is the usual practice to increase the air temperature of the oven a degree or two for practical heat treatment. The oven design in Figure 2 has been used as a basis for the development of larger units of sufficient size (2000-pounds capacity) to be of value in an industry-wide control programme.

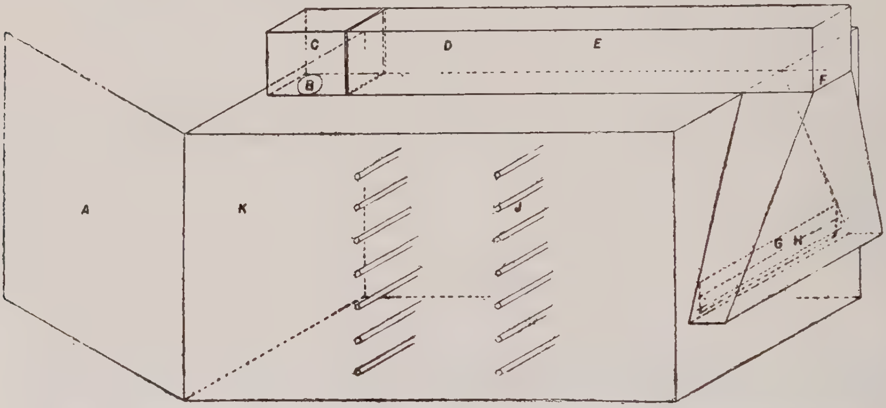

Fig. 2. Diagramatic sketch of an electric oven with forced air circulation used for the heat treatment of sugarcane seed pieces as a means of ratoon stunting disease control.

A. Door which tightly closes over front end.
B. Air outlet in oven opening into blower.
C. Electrically driven centrifugal air blower of approximately 1000 cu. ft. per min. cap.
D. Air duct which conducts air back into oven at "G".
E. Area of duct in which electrical resistance elements of approximately 5000-W are located.
F. Location of thermoregulators.
G. Air inlet into oven.
H. Adjustable air deflectors in opening "G".
J. Removable sugarcane support racks made of 3/4" iron pipe.
K. Insulated heat treating oven chamber of air tight construction.

SUMMARY

The effects of ratoon stunting disease in Louisiana can be demonstrated by yield trials and inoculation experiments in relatively large populations. Precise means of identifying the disease in individual stalks are lacking. The use of nodal discoloration is a possibility, but evidence regarding its continuous association with the disease-producing factor in Louisiana is still far from conclusive. The disease prevents normal stands by reducing germination, and by the death of young shoots after germination. The demonstrated reduction in yields caused by the disease warranted the establishment of a practical control programme based on the Australian work, although evidence is inadequate as to the effectiveness of heat therapy in eradicating the pathogen from treated cane in Louisiana. Air has been selected in preference to water as the medium for the treatment of seed pieces. This selection is based mainly on the beneficial effects upon stand, and decrease in susceptibility to injury in handling. A sketch of a hot-air-treating chamber is included, the basic design of which has been incorporated in the construction of large ovens for treating seed cane on a commercial scale.

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DISCUSSION

Replying to a query made by Mr. Kirtikar, Dr. Abbott stated that older varieties, which are more saturated with virus, gave better response to heat treatment. Mr. Sharma considered the occurrence of Ratoon Stunting disease in India, as rather premature. He presented data on certain varieties, which showed that short spindly canes had discoloration of vascular bundles but gave no response to Hot Water Treatment. Mr. Gumaste referred to the stunting type of disease observed in Co. 419 in the Bombay State, which could be controlled by Hot Water Treatment at 50°C. for two hours. The Chairman remarked that the disease to which Mr. Gumaste had referred was Grassy Shoot disease and not Ratoon Stunting. The Ratoon Stunting disease had only very recently been suspected by Dr. Chilton in U.P. (this has not been confirmed in subsequent observations). He doubted, whether the disease to which Mr. Sharma referred was at all a virus disease.

Dr. E. V. Abbott then presented his paper.

Paper

SOME ASPECTS OF TESTING SUGARCANE VARIETIES FOR RED ROT RESISTANCE

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During the past quarter century there has been great expansion in sugarcane breeding in most of the countries of the world where this crop is of major importance, with many thousands of seedlings being produced annually. Tests of resistance to the principal sugarcane diseases occurring in the various countries have generally been introduced at some point in the subsequent screening through which the seedlings pass in the process of selecting out the desirable commercial types. The emphasis placed on disease resistance tests varies considerably from country to country, reflecting somewhat the differing commercial importance of the diseases. Methods of testing for resistance also vary widely, but where large seedling progenies are dealt with, artificial inoculation techniques have often been developed in an effort to determine well in advance of final agronomic evaluation a seedling's reaction to specific diseases.

While red rot (*Physalospora tucumanensis* Speg.) is widely distributed over the sugarcane-growing world, it is only in the northern or southern fringes of the latitudes in which sugarcane is grown commercially that it has generally been of sufficient importance to justify resistance tests by artificial inoculation methods. Two countries in which the disease has assumed epidemic proportions from time to time are India and continental United States. In India, it is of principal importance as a disease of standing cane in the field ; in Louisiana, it is primarily a disease of seed cuttings, while in Florida, it may be of importance in either seed or standing cane. In both countries sudden and widespread failures of major commercial varieties from red rot have occurred, and as a consequence, breeding and testing for red rot-resistance is a major objective in the varietal improvement programmes. The fact that less success has been achieved in developing varieties as stable in their resistance to red rot as to other important diseases is disturbing both to the pathologists and breeders concerned, and justifies an inquiry into the reasons, and an attempt at an appraisal of the status of efforts toward production of red rot-resistant varieties.

In the United States a high degree of success has been achieved in developing commercial type canes that are resistant to mosaic. In Florida, mosaic has been of virtually no importance for many years as the result of replacing susceptible with resistant varieties. In Louisiana, the acreage devoted to mosaic-resistant varieties has progressively increased as C. P. canes have replaced those of foreign origin, until in the 1954 crop approximately 95 percent of the acreage was in resistant varieties. Varieties released to growers as resistant to mosaic have remained resistant to prevalent strains of the virus*.

Similarly, varieties released as resistant to Pythium root rot have remained more stable in their reaction to this disease after a period of commercial culture, although there is evidence of increasing prevalence of more virulent forms of the pathogen (10). With red rot, however, the situation has been quite different. P.O.J. 213, for example, considered resistant to red rot when released in Louisiana (8), failed suddenly from the disease a few years later (1). C.P. 34/120, recognised as moderately susceptible when released, also showed widespread stand failures which contributed to its commercial decline. In India, the failure of Co. 213 can be cited as an outstanding example of sudden failure of a variety from red rot, after becoming a major commercial cane (6) (9). More recently, in Louisiana, C.P. 36/105 and C.P. 44/101, pronounced highly resistant to red rot when released have shown enough evidence of red rot injury to seed cuttings to suggest that there may be a change in their reaction to the disease.

The following may be offered as reasons why less progress has been made in producing varieties resistant to red rot than to some other diseases :

1. A high degree of resistance or immunity to red rot, comparable with that to mosaic, to serve as a source for breeding, is not known among sugarcane varieties. Some sugarcane varieties can be considered immune to mosaic— at least there is no record of mosaic on them and it has not been possible to infect them by mechanical transmission technique. It is doubtful that any variety can be considered immune to red rot. Infection can be induced in all of the many forms of Saccharum that have been tested by the United States Department of Agriculture. There are, however, wide differences in resistance to infection by natural means and in the degree to which the pathogen spreads within the tissues following infection, and this fact is taken advantage of in breeding.

2. Weather and other environmental conditions may so favour the red rot fungus and so adversely affect the sugarcane plant that the balance is tipped far in favour of the pathogen, with resultant severe disease injury to varieties that are ordinarily resistant (2). This adverse effect of weather is more likely to occur with seed cuttings after planting than with standing cane.

3. *Physalospora tucumanensis* is more variable pathogenically than some other sugarcane pathogens are known to be, with resultant greater likelihood of the development in nature of specialized biologic races. While it is known that there is a wide range of pathogenic variability in the red rot fungus, the limits of such variation have not been determined owing to the lack of a basis for exact separation of physiologic races comparable with that which has been accomplished with the cereal rust fungi, for example. But every pathologist with experience in

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*Isolated instances of mosaic in C. P. 36/105 and C. P. 44/101 in commercial fields in Louisiana resulted from infection by the less prevalent Strain A, which was not included in the resistance tests.

studying resistance to red rot in sugarcane varieties is aware of the great variability that exists. The development of specialized races of the pathogen has led to commercial failure of several varieties originally considered resistant, and while other varieties have remained more stable in their reaction to the disease over a period of time, exposing them through artificial inoculation to even a relatively small population of isolates of the fungus will usually reveal widely differing degrees of susceptibility. As an example the history of Co. 281 in Louisiana may be cited. Grown as an important commercial variety from 1931 until about 1943, it remained resistant during its commercial life, and for many years was used as the standard of resistance in the varietal resistance tests of new seedling varieties. However, in 1931 an isolate of *Colletotrichum falcatum* (designation of the red rot pathogen then in use) was isolated which was very virulent toward it (1). Although this race fortunately did not become prevalent while Co. 281 was grown commercially, there was later a progressive change in the reaction of this variety to isolates of the fungus obtained in the annual surveys of the red rot flora, and in recent years it has shown such a high degree of susceptibility to a majority of current isolates that it would now be classed as very susceptible to the disease.

Confronted with the uncertainty of a variety's resistance to red rot because of the variability of the organism, the pathologist is faced with the problem in testing new varieties, of determining the extent to which he can anticipate development of specialized races of the fungus on a given variety and thus prevent its failure from the disease. Knowledge of the potential variability of the pathogen is therefore important.

It is known that races of *Physalospora tucumanensis* of differing virulence may arise in two ways : (1) hybridisation, since the sexual stage occurs commonly in nature (3) (4) ; and (2) mutation (5). The question then presents itself as to whether it would be possible to anticipate the extent of variability which may occur.

It has been suggested* that an attempt might be made to exhaust the possibilities of production of new, highly virulent biological races of the fungus through artificial hybridisation between large numbers of isolates obtained from a given commercial area. In the present state of our knowledge this does not appear to offer a practical solution for the following reasons : (1) the requirements in personnel and laboratory facilities would be beyond the resources of most institutions ; (2) even if it were economically feasible to undertake the large-scale artificial hybridisation and testing that would be necessary, it seems doubtful that there would be any assurance of exhausting the possibilities of production of specialized virulent races that might arise in nature ; (3) conceivably a potentially valuable variety might be discarded because of susceptibility to a highly virulent race of the fungus produced by hybridisation, but which might never arise in nature.

If this suggestion is not accepted as offering at present a practical solution of the problem, it nevertheless has merit in focusing attention on the need for more basic studies of the pathogen and host-parasite relationships. Adequate information on the genetics of the pathogen, and on the nature of and inheritance of resistance to the disease might lead to the development of more precise methods of cmeasuring pathogenic variability of the fungus and relative resistance of varieties, and point to more effective means of attacking the problem of anticipating or preventing red rot epidemics.

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*By Mr. K. L. Khanna in personal communication.

Meanwhile, an alternative must be sought . The plan now followed by the United States Department of Agriculture is outlined, with the realization that it may represent an oversimplification of the problem. Each year new seedling varieties are tested against a mixture of isolates of the fungus obtained currently from the principal commercial varieties. During the winter commercial fields are examined for red rot damage, and isolates made where this occurs. Further isolates are obtained from standing cane during the growing season. In the fall, 8 to 10 isolates are chosen at random but with consideration to representation from the principal varieties, particularly those considered resistant to red rot. These are grown on oatmeal agar medium, a spore suspension from each is made in dilute oatmeal decoction ; and the suspensions are then mixed prior to inoculation. A spore load of approximately 25 spores in a low power field is used. Inoculations are made by introducing a few drops of the suspension into a small hole in the utting made with a steel punch ; the cuttings are incubated in a controlled temperature room at 20-21° C for three weeks ; and resistance ratings are made in comparison with control varieties that are included in the tests. Further study of red rot reaction of seedlings in advanced agronomy trials is made in field plantings.

By this procedure new varieties as well as those grown commercially are tested against a sample of races of the fungus occurring currently in nature. The success achieved in detecting susceptible or resistant varieties will depend on the adequacy of the sampling of the red rot flora ; and what is considered an adequate sample will depend on the pathologist's experience with the disease in a given area. In Louisiana, this method of testing has resulted in the early elimination of varieties that are highly susceptible to red rot, and permitted selection of those resistant to isolates of the fungus against which they were tested —presumably representative of the current red rot flora.

It cannot be claimed that the method provides assurance that strains of the fungus will not subsequently arise that may be virulent toward a variety that was resistant to those used in the tests. Losses from red rot have continued to occur, though on a much reduced scale. But as expressed by Coons (7), "Even though the parasites are on the move, and a once-prized variety may pass out of the picture because of a disease, a defeatist attitude is not warranted. Nevertheless, the facts are patent that unless the exposure encompasses about the ordinary range of virulence exhibited by the gamut of biotypes of the pathogen likely to be encountered, the resistant type as developed may be very restricted as to its area of adaptation and short-lived as an agricultural variety."

The plan outlined is aimed at encompassing the range of virulence likely to be encountered. It provides current information as to the red rot situation, and by including commercial varieties in the tests, permits detection of any indication of the failure of a variety. It may provide a forewarning but not a preventive of red rot epidemics. That still remains a challenging problem for the breeder and the pathologist to solve.

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DISCUSSION

Opening the discussion, Mr. Khanna stated that composite inoculum did not give uniform results in India. With the present knowledge, it was not possible to forecast the coming up of new strains, which was so very essential for the raising of a sound crop. He felt that it would be desirable if a large number of isolates are collected and also new strains are produced in the laboratory by mutation, hybridisation or atomic radiations, and then to test the varieties under rigorous artificial conditions, so that the really resistant material could be picked up easily. Dr. Abbott replied that in their country composite inocula was giving quite satisfactory results. Regarding the fundamental studies on how these new forms arose, he stated that if the necessary funds, facilities and personnel were available, it would be a useful study.

Dr. Chilton pointed out that in Louisiana, they had made large scale isolations, but did not find any physiologic specialisation. The red rot fungus had been found to be homothallic, and, therefore, there was not much chance of getting new isolates by hybridisation. Moreover, mutation was very rare. He wanted to know if these new forms arose by mutation and how they got spread over to large areas simultaneously to cause widespread epidemics.

Mr. Rafay observed that the methods of testing cane varieties had varied considerably from time to time and even the strains used for inoculation varied from light to dark. He could not say whether the latter were due to principles involved for Mendelism or Lysenkoism. If the environment was unfavourable year after year, he added, the strains changed without mutation.

Dr. Tandon observed that if absolute resistance for this disease was not to be found as made out by various speakers, it was not clear how legislation for the control of diseases worked in Australia, and how far this could prolong the useful life of a commercial variety.

Dr. Vasudeva remarked that the object of suggested fundamental studies was to find out the conditions under which mutations occurred or new forms arose and how the large inocula were built up. Regarding composite inocula, he stated that sometimes the results were quite unexpected. He did not know whether this could be explained on the basis of enzyme theory.

Mr. Harbans Singh then presented the following paper.

Paper

VARIETAL REACTION TO RED ROT DISEASE OF SUGARCANE IN THE PUNJAB

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INTRODUCTION

Red rot disease of sugarcane caused by the fungus *Colletotrichum falcatum* Went was first recorded in India by Barber in 1901 and a lot of work on this disease was done by Butler from 1906 onwards. In the Punjab, this disease attracted the special attention of the Department of Agriculture only in 1925, when Luthra reported that the thick chewing canes (*officinarum*) were found seriously attacked by this disease at Ferozepur (District Ferozepur) and at Shahbad (District Karnal). The disease appeared in an epidemic form in Bihar and Uttar Pradesh in 1939-40 and 1946-47 and has also been recently recorded in certain localities in the Punjab, causing considerable damage to some of the Coimbatore canes (1949-55).

Recently, a good deal of work has been done on different aspects of this disease by Abbott (1938) in Louisiana, Carvajal and Edgerton (1944) in Louisiana and Chona (1950) and (1954) in India. The control measures, so far advocated in the form of seed selection, cultural methods and the use of resistant varieties, have undoubtedly proved very effective, where taken up on a cooperative basis. But, of the various methods, the introduction of resistant varieties is agreed by all, to be the best approach to save the cane growers from the heavy losses caused by this disease.

Different sugarcane varieties were found to behave differently towards this disease under natural conditions, in the affected localities. It has also been observed that a variety found fairly resistant to a particular strain of this disease, suffered heavy losses in years of severe attack. It has not, so far, been possible to produce a sugarcane variety completely resistant to pests and diseases. Studies are in progress to find out varieties combining tonnage, quality and resistance to red rot and the reaction of different varieties to different isolates.

LOCATION

The trials reported in this paper were carried out at the Main Sugarcane Research Station, Jullundur and the Sub-station at Jagadhri. The soil of the Jullundur station is sandy loam while that of Jagadhri is loam to clay loam. These two localities, also differ in their climate. The weather data for 1954-55 have been given in Table I.

TABLE I

Month	Mean maximum temp. °F.	Mean minimum temp. °F.	Rainfall in inches	Humidity %
June 1954 Jullundur/Jagadhri	105.9	81.8	0.39	39
	98.6	88.3	1.61	52
July 1954 Jullundur/Jagadhri	96.1	78.8	4.39	68
	95.4	82.4	15.02	76
Aug. 1954 Jullundur/Jagadhri	98.8	79.8	1.32	64
	93.5	81.2	7.35	78
Sept. 1954 Jullundur/Jagadhri	91.9	75.9	11.38	77
	94.9	79.6	7.70	77
Oct. 1954 Jullundur/Jagadhri	86.2	57.2	1.13	62
	86.1	64.3	3.18	73
Nov. 1954 Jullundur/Jagadhri	83.0	46.8	Traces	58
	73.0	54.4	Traces	77
Dec. 1954 Jullundur/Jagadhri	71.4	38.8	Traces	61
	70.4	51.6	Traces	78
Jan. 1955 Jullundur/Jagadhri	66.1	41.0	1.51	70
	70.1	44.1	6.54	72
Feb. 1955 Jullundur/Jagadhri	74.8	41.5	0.02	61
	73.6	53.8	0.47	77
Mar. 1955 Jullundur/Jagadhri	85.0	56.8	2.15	58
	86.8	65.6	0.78	76
Apr. 1955 Jullundur/Jagadhri	91.8	57.6	0.39	41
	99.4	72.2	0.243	72
May. 1955 Jullundur/Jagadhri	97.3	67.6	0.28	40
	102.4	79.3	0.5588	57

MATERIAL AND METHODS

About one and a half dozen varieties, which showed promise for the future, have been tested each year in these trials. These were planted at the normal planting season (March) in rows 2½ ft. apart in three-row plots of 20-25 ft. length. Pure culture of *C. falcatum* isolate 244 was used for inoculations in the varietal resistance tests. In the other series of trials nine other isolates were also included. The different varieties included in the relative resistance trial were inoculated in November 1949 to 1953 and in September 1954 and similarly, in the trial on the comparative virulence of different isolates, the varieties were inoculated in November 1953 and in October 1954. The plug method of inoculation was used in these trials. Data on the linear spread of infection in the case of different varieties or isolates, were recorded 4 to 5 months after the inoculation, by splitting open the inoculated canes. For grading the varieties in regard to their reaction, the criterion applied was the ratio of the linear spread of infection in a variety to the maximum spread of infection in the most susceptible variety in the season. Varieties showing 25% or 15 inches of linear spread of infection, were graded as resistant, those with 50% or 30 inches infection as moderately-resistant and others as susceptible.

RESULTS AND DISCUSSION

TRIAL I—RELATIVE RESISTANCE OF DIFFERENT VARIETIES

These studies were taken up in detail, in 1949 and have been carried out at Jullundur and Jagadhri. The canes of different varieties were inoculated by the plug method. Isolate *Cf.* 244 was used in these tests. The results are presented in Table II and the average linear infection in the case of certain varieties for 1953-1955 is depicted in Fig. 1.

The data given in Table II, clearly indicate the differential behaviour of cane varieties to red rot and the necessity of testing the varieties with regard to their reaction to red rot disease before they are released for general cultivation. Co. 312, which occupies over 50% of the total cane area in the Punjab, has been found susceptible whereas Co. 421, Co. 453 and Co. L. 9, on the whole, showed high resistance to this disease, under natural conditions, as compared to other varieties. Even Co. 453 was found to have been attacked by this disease, in certain fields, in the area of the Saraswati Sugar Mills, Yamuna Nagar, whereas Co. L. 9 in the same locality showed complete freedom from it. Evidently, infection through soil, irrigation water and nodal infection seem to play an important part in the behaviour of a variety under natural conditions. In future studies, it is proposed to try these modes of infection, besides the plug method.

Compared to November, the month of September seems to be more favourable for the purpose of inoculation, evidently, due to the higher temperature approximating the optimum temperature for the growth of the fungus.

TRIAL II—COMPARATIVE VIRULENCE OF DIFFERENT ISOLATES OF *C. FALCATUM* WENT

According to Abbott (Louisiana) and Chona (India), the different isolates can be divided into three main classes, distinguished mainly by the colour and texture of their fungal colonies, such as light type-white colour and profuse sporulation, dark type-dark colour sparse sporulation and an intermediate type. It has also been recorded that light type isolates are generally more virulent than the other two types. Different isolates derived from the diseased canes from the Punjab, Uttar Pradesh and Bihar and obtained from the Indian Agricultural Research Institute, New Delhi, have been studied for their comparative virulence on a group of 8-10 varieties. Thirty canes of each variety were inoculated. Thus, each isolate was tested on about 240-300 canes. All the isolates used in this trial were of light type. In this case also, the plug method was employed. *Cf.* 244 isolated in 1946 from diseased cane from Bhojipur (Uttar Pradesh) and supplied by the Indian Agricultural Research Institute, New Delhi was taken as standard. The comparative average linear infection is graphically shown in Fig. 2 and the results are briefly set out in Table III.

FIG. I SHOWING REDROT INFECTION IN CERTAIN VARIETIES AT JULLUNDUR & JAGADHRI

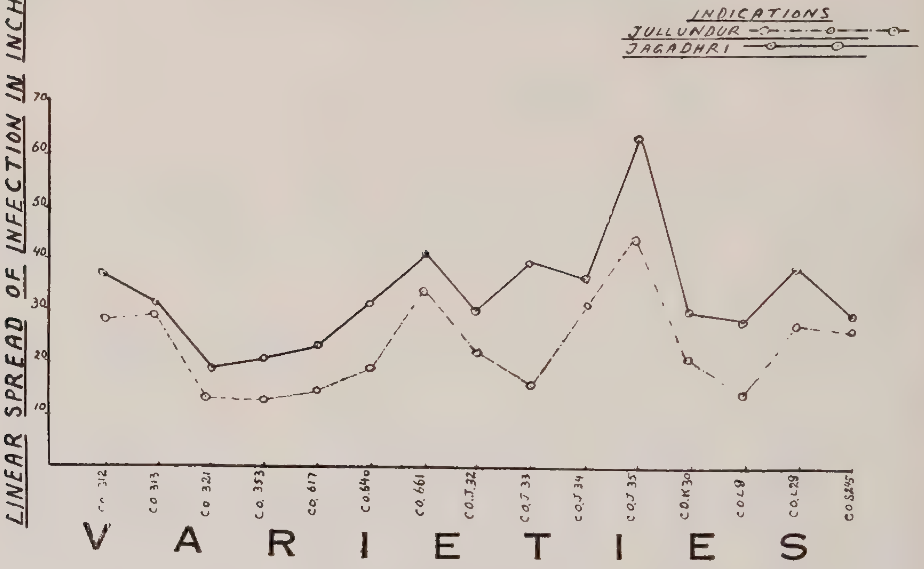

FIG. II SHOWING COMPARATIVE VIRULENCE OF DIFFERENT REDROT ISOLATES

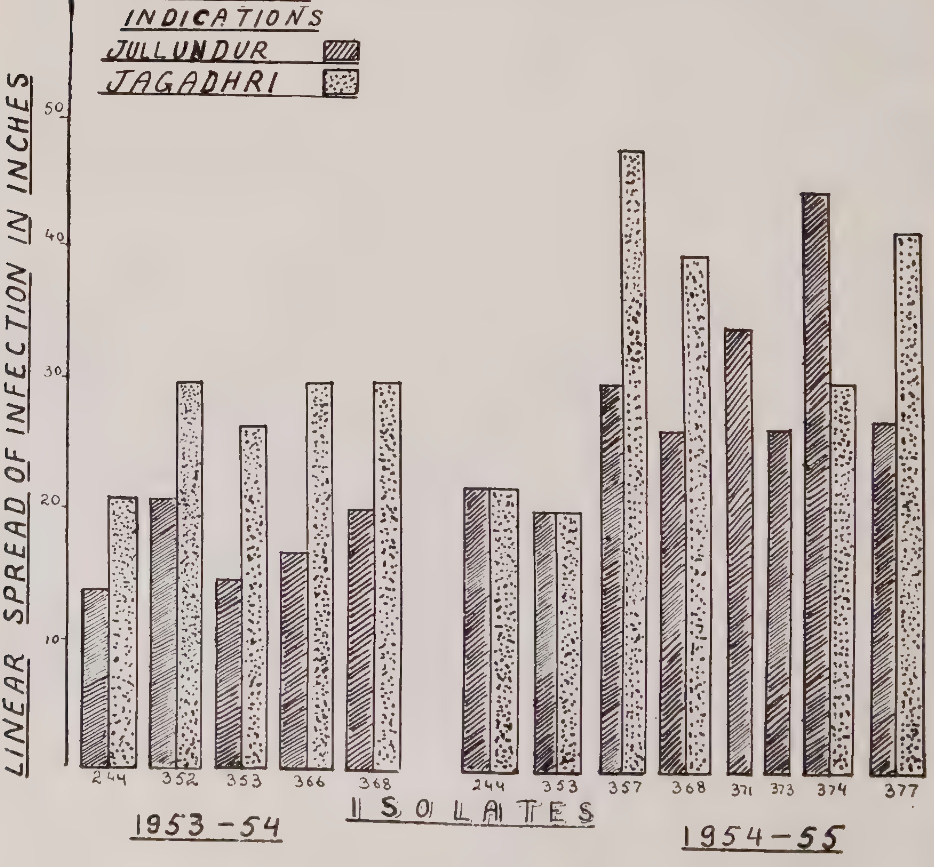

TABLE II

LINEAR SPREAD OF RED ROT INFECTION IN IMPORTANT CANE VARIETIES AT JULLUNDUR/JAGADHRI FROM 1952-53 TO 1954-55

Variety	Linear spread of infection in inches			Grading		
	1952-53	1953-54	1954-55	Resistant	Moderately resistant	Susceptible
Co. 312	41.3/47.7	18.8/25.6	25.4/38.0		1 MR	5 S
Co. 313	41.0/45.0	— /21.2	16.2/27.9		2 MR	3 S
Co. 421	— /31.6	— / —	13.1/24.3	1R	2 MR	
Co. 453	— /20.0	10.3/ —	14.0/20.5	1R	3 MR	
Co. 617	14.4/24.6	9.3/ —	18.9/21.1	1R	4 MR	
Co. 646	— / —	17.3/ —	19.7/31.2		2 MR	1 S
Co. 661	— / —	30.6/ —	37.1/40.3			3 S
Co. J. 32	14.5/30.3	24.4/19.4	26.5/35.6		2 MR	4 S
Co. J. 33	14.5/42.0	16.0/34.9	— / —			4 S
Co. J. 34	— / —	17.2/ —	46.5/35.0			3 S
Co. J. 35	— / —	21.9/ —	62.5/62.5			3 S
Co. J. 36	— / —	14.4/ —	25.2/ —		2 MR	
Co. K. 30	33.1/29.1	13.7/22.4	18.2/33.0		3 MR	3 S
Co. L. 9	13.6/28.3	13.5/19.7	14.2/33.9	2R	2 MR	2 S
Co. L. 29	31.2/58.0	18.3/20.7	33.8/33.5			6 S
Co.S. 245	25.8/24.0	— /23.4	— /35.4		2 MR	2 S

'R' is resistant, 'MR' moderately resistant and 'S' susceptible. The numerals signify the number of times a variety behaved as such.

TABLE III

AVERAGE LINEAR SPREAD OF INFECTION IN INCHES AT JULLUNDUR/JAGADHRI

Isolate No.	Co. 312	Co. 313	Co. 421	Co. 453	Co. 617	Co. K. 30	Co. L. 9	Co. L. 29
				1953-54				
244	18.8/25.6	— /21.2	—	10.3/ —	9.3/ —	13.7/22.4	13.5/19.7	18.3/20.7
352	31.3/31.1	28.4/28.5	19.0/ —	12.8/ —	16.6/ —	15.0/15.7	12.4/23.6	29.9/30.6
353	15.5/26.4	20.0/27.0	12.1/ —	7.7/ —	7.3/ —	17.9/19.5	10.8/21.8	22.4/35.9
366	25.8/35.6	24.4/32.3	12.1/ —	7.3/ —	8.5/ —	10.5/26.9	13.3/21.6	31.5//29.7
368	30.7/33.6	27.9/30.0	16.6/23.5	15.1/ —	12.0/ —	13.0/26.1	12.7/22.5	31.0/42.7
				1954-55				
244	17.1/32.2	27.5/26.3	14.5/19.8	22.9/17.6	26.7/14.6	15.1/20.8	23.0/19.2	23.0/24.1
353	13.2/28.0	30.3/26.5	13.2/15.2	24.6/16.1	17.8/13.1	13.4/19.7	19.1/14.3	25.7/24.1
357	45.2/76.6	29.3/44.4	40.1/65.3	13.1/49.1	20.3/24.9	17.7/57.0	23.1/42.1	45.3/61.5
368	42.2/59.1	39.6/55.6	20.6/64.6	17.8/20.2	16.8/23.7	17.4/28.3	12.8/19.4	41.5/43.7
371	57.6/ —	48.9/ —	22.2/ —	18.0/ —	20.6/ —	20.3/ —	18.8/ —	64.0/ —
373	42.4/ —	34.0/ —	21.2/ —	27.5/ —	20.2/ —	18.5/ —	15.7/ —	30.3/ —
374	65.6/55.2	54.3/38.0	41.9/18.7	50.8/21.5	21.4/19.7	32.0/24.1	22.4/14.8	65.1/45.7
377	34.8/64.4	28.1/36.8	38.2/54.4	32.4/34.8	18.1/19.1	15.7/30.1	20.4/46.6	28.1/46.1

— Means not tested

PARTICULARS OF ISOLATES

244 isolated from Co. 312 from Bhojipur (U.P.) in 1946 and used as standard.
352 isolated from Co. J. 33 from Hundewala (Punjab) in 1952.
353 isolated from Co. J. 32 from Hundewala (Punjab) in 1952.
357 isolated from Co. 453 from Haripur (Punjab) in 1952.
366 isolated from Co. L. 29 from Hundewala (Punjab) in 1952.
368 isolated from Co. L. 29 from Hundewala (Punjab) in 1952.
371 isolated from Co. 312 from Rohat (Punjab) in 1953.
373 isolated from Co. 356 from Gorakhpur (U.P.) in 1951.
374 isolated from Co. 453 from Faizabad (U.P.) in 1952.
377 isolated from Co. 453 from Dermarwa (Bihar) in 1949.

Barring isolate 353 in 1954, all the other isolates included in the tests have shown greater virulence than the standard isolate 244. Isolates 357 and 374 showed the greatest virulence at Jagadhri and Jullundur, respectively. Isolate 357 was obtained from the diseased canes of Co. 453 of the Jagadhri area, while isolate 374 was derived from the diseased canes of the same variety from Faizabad, Uttar Pradesh. Isolate 357 obtained from the Jagadhri canes, was found to cause greater linear infection under Jagadhri conditions as compared to its effect under Jullundur conditions. This may be due to climatic differences at the two places. (Table I).

The fact that Co. 453 and Co. 313 found moderately resistant to isolate 244 in the tests, showed fairly high disease incidence in certain localities, where these varieties had been in cultivation for a number of years, can now be explained that in such cases these might have been attacked by an entirely different isolate of the fungus. This brings out that the varieties should be tested with a large number of isolates of high virulence and where possible, such tests should be carried out with the isolates, under the very conditions from where these isolates have been obtained. Like the testing of the suitability of particular sugarcane varieties for different sets of soil and climatic conditions, the above studies reveal the necessity of finding out varieties for successful cultivation in different localities by virtue of their resistance to specific *Cf.* isolates recorded in such localities.

As it would appear from the above, the different isolates have not shown any specificity to different varieties, indicating thereby that they do not belong to different physiologic races.

SUMMARY

1. Red rot (*C. falcatum* Went) recorded in India for the first time in 1901 and in the Punjab in 1925, has appeared in epidemic form in Bihar and Uttar Pradesh in the past years. It has also now been recorded, doing appreciable damage in certain localities in the Punjab.

2. Jullundur and Jagadhri, where trials with regard to relative resistance of different sugarcane varieties and the comparative virulence of different isolates have been carried out, differ in regard to their climatic conditions. Greater linear infection at Jagadhri leads to indicate that conditions there, are more favourable for the development of this fungus.

3. Varietal tests have shown that different varieties react differently even to one and the same isolate.

4. Different isolates differ widely in their virulence and generally an isolate derived from a certain locality, proved more virulent when tried under those very conditions.

5. No physiologic specialisation has been indicated in the case of different isolates included in the trial.

ACKNOWLEDGMENTS

The authors gratefully thank Dr. R. S. Vasudeva, Head of the Division of Mycology and Plant Pathology, Indian Agricultural Research Institute, New Delhi and Dr. B.L. Chona, Systematic Mycologist, Indian Agricultural Research Institute, New Delhi, for the supply of cultures, valuable advice and scrutiny of the data.

This work has been done under the Sugarcane Research Scheme, Punjab, financed jointly by the Indian Central Sugarcane Committee and the Punjab Government. The authors thankfully acknowledge this help, without which, it would not have been possible to carry out these studies.

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DISCUSSION

Opening the discussion, Mr. Khanna pointed out that Co. 453 was found to be resistant in Punjab, while it was susceptible in other parts of India. He wondered if this could not be due to different inocula being used at different places. He, therefore, suggested that the work of testing should be coordinated. Mr. Kirtikar pointed out that the discrepancy that the isolates proved more virulent in their own environment, was not borne out by the data presented, as U.P. isolate had given more infection in Punjab. Mr. Singh replied that the figures had been wrongly printed.

In the absence of the author the following paper was taken as read.

Paper

A NEW SPECIES OF *HELMINTHOSPORIUM* CAUSING DISEASE IN SUGARCANE AND OTHER GRASSES

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At the present time, only two species of *Helminthosporium* have been reported as being parasitic on sugarcane (*Saccharum officinarum* L.) in the United States. *H. sacchari* (van Breda de Haan) Butler causes the eye-spot and *H. stenospilum* Drechsler causes the brown-stripe disease. According to Abbott (1) *H. sacchari* is the only one of major importance. Parris (5) in reviewing the status of these diseases and the fungi causing them, recorded also the presence of *Helminthosporium rostratum* Drechsler associated with *H. sacchari* from brown-stripe lesions of sugarcane and from eye spot of lemon grass, mentioning that it is considered a saprophyte. The other host plants of *H. sacchari* were given as Napier grass and lemon grass.

This paper describes another species of *Helminthosporium* distinct from the two parasitic and one so-called saprophytic species listed above and demonstrates its parasitism on sugarcane (*Saccharum officinarum* L.), Para grass, (*Panicum purpurascens* Raddi), Napier grass (*Pennisetum purpureum* Schumach) Pearl millet (*Pennisetum glaucum* (L.) R. Br.) and to a very slight degree only on lemon grass (*Cymbopogon citratus* D. C.). Some comparisons are also made between the morphological and growth characteristics of this new species and *H. sacchari.*

Although *H. sacchari* has been reported by Weiss (7) as attacking the leaves of pearl millet (*Pennisetum glaucum*) in Hawaii, inquiry from pathologists[1] who made observations in Hawaii failed to locate a published reference to this and the record is probably based on collections only. However, Johnson (2) mentioned this fungus as occurring on pearl millet in the Southern U.S. where it infects and blackens the seed and causes a conspicuous leaf spot. Luttrell[2] also advised that this *Helminthosporium* leaf blight is the commonest disease of pearl millet in Georgia and also that a *Helminthosporium* similar to the one on pearl millet causes a leaf spot of brown-top millet (*Panicum fasciculatum*) in that State.

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[1] Private communications were received from Mr. J. P. Martin, Hawaiian Sugar Planters' Association, Honolulu, T.H. and Dr. G.K. Parris, Mississippi State College, Mississippi.

[2] Private communication from Dr. E. S. Luttrell, Georgia Agric. Exp. Sta., Experiment. Ga. U.S.A.

PRELIMINARY OBSERVATIONS

In the Florida Everglades region bordering Lake Okeechobee to the south and east, close to 40,000 acres of sugarcane have recently been under cultivation. Adjacent to much of this planting, almost the same acreage of pasture grasses have been planted in recent years. Among these, Para grass (*Panicum purpurascens* Raddi) is very common. In fact it had become widespread two decades ago as a drainage canal and ditchbank pest. Guinea grass (*Panicum maximum* Jacq.) and Napier grass (*Pennisetum purpureum* Schum.) once cultivated, have escaped and are also widespread.

Normally, Para grass makes a very luxuriant growth in mid summer and for that reason is extensively used for beef cattle grazing, hay and silage production. However, on very low mineral peat soil in the Everglades area during August and September 1952, a very serious leaf disease epidemic appeared adjacent to sugarcane plantings near Clewiston, Florida, destroying all the leaves except the first and second ones from the tip and even these were badly spotted. Several hundred acres were thus rendered virtually worthless for pasture or hay at the very time when highest production should have been possible.

An examination of the diseased leaves showed that a species of *Helminthosporium* was associated with the dead and dying spots. Although, Lefebvre and Johnson (3) had previously recorded a *Helminthosporium* from Para grass in 1941, causing a leaf spot, no description of the disease or of the fungus causing it was given and the latter was not referred to under a specific name.

NOTES ON THE PARA GRASS LEAF DISEASE

Typical leaf spots on this host are shown in Figure 1. Infection courts appear at first as minute reddish-purple, oval spots surrounded by a yellowish halo, which soon become brown and then straw-coloured in the centres. Spots are often so numerous that some coalesce to form large irregular-shaped blotches with straw-coloured centres and reddish purple margins. In general, spots resemble closely those of eye-spot of sugarcane. Under favourable weather conditions, the lower leaves wither and dry up completely while the younger ones show varying degrees of destruction, including even the youngest ones.

THE PARAGRASS *HELMINTHOSPORIUM*

Ten single-spore cultures were prepared from spores scraped from typical disease lesions collected in August. By holding infected leaves in a damp chamber overnight, abundant spore formation took place. After scraping the spores off with a sterile scalpel, dilutions were prepared in sterile water before plating in Petri dishes poured with nutrient starch "Difco" agar containing 150 ml. sugarcane juice per litre. Before pouring the melted agar, 1 drop of 50% lactic acid was added to each plate to curb bacterial growth. Isolated germinated spores selected with the aid of a microscope were transferred to slanted nutrient agar tube cultures of the same medium used for Petri plates. After a few days, the cultures were used to inoculate tube cultures prepared with autoclaved young Para grass leaves.

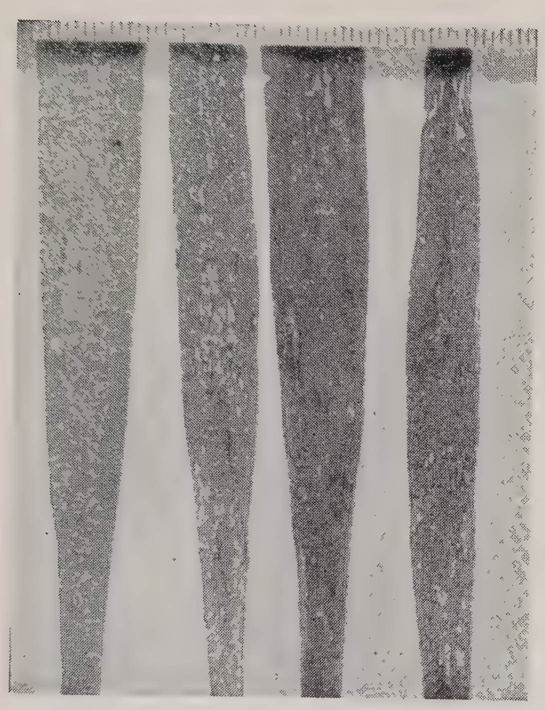

Figure 1. Typical leaf spots on Para grass—*Panicum purpurascens*, caused by *Helminthosporium purpurascens* sp. nov. (Scale divisions = 1 mm.).

Examination of all ten cultures, both on agar and Para grass leaf media showed no apparent differences among them in appearance of growth or of spore and conidiophore characteristics.

After 4 days growth on the modified " Difco " starch agar medium, colonies on Petri plates were light olivaceous to almost greenish white, with whitish border —2 mms. wide.

After 7 days, the colonies became much darker and could be classed as olivaceous except for the whitish border. Conidiophores fuscous and may or may not be geniculate, 92.5—330μ × 5.6μ, biseptate to pleuriseptate. Spores dark olive brown, 11.1—44.8 × 9.3—14.8μ (average of 100—29.7 × 12.0μ) usually 1—6 septa. Figure 2, D and G show typical spores of this fungus.

Lefebvre and Johnson (3) recorded the occurrence of *Helminthosporium* sp. on Para grass, *Panicum Purpurascens* Raddi from material collected in 1941 at Gainesville, Florida by G.E. Ritchey. Weiss (6) in 1945, again reported *Helminthosporium* sp. as occurring associated with leaf spots on Para grass in Florida. Whether the fungus associated with the Para grass leaf disease which occurred locally in epidemic proportions in 1952, is the same as that reported by others previously is not known, since herbarium or culture materials have not been compared by the writer. It is entirely possible that more than one *Helminthosporium* may be capable of infecting this host and causing distinct diseases. A sub-culture of the local fungus was submitted to Dr. Paul L. Lentz of the Division of Mycology and Disease Survey, U.S. Department of Agriculture in 1952 and he verified the placement in the genus *Helminthosporium* but was unable to determine the species, because of limited facilities for culture work. Luttrell (4) in 1951 gave a key to species of *Helminthosporium* reported on grasses in the United States, but since the one recorded on Para grass has apparently never been described, it was not included. In fact, based on the morphological and other characters described in this paper, it does not fit the description given for any of the described species. The spores are much smaller than those of *H. sacchari* or *H. stenospilum*, already described as occurring on sugarcane. Johnson (2) in 1953, while reviewing the leaf diseases of grasses in the southern United States did not mention the *Helminthosporium* on Para grass, since the latter is not an important pasture or forage grass, except in the southern part of Florida.

INOCULATION EXPERIMENTS WITH THE PARA GRASS *HELMINTHOSPORIUM*

SERIES I—PARA GRASS, (*PANICUM PURPURASCENS*)

The writer could find no record of experiments in the literature proving that the *Helminthosporium* sp. associated with Para grass leaf spots was parasitic. Using a single [spore strain of the fungus, isolated from typical leaf spots and cultivated on sterilized portions of Para grass leaves for 10 days, a spore suspension was prepared with sterile distilled water and atomized on freshly collected healthy leaves growing on four apical shoots and placed separately in stoppered, sterilized glass cylinders for incubation at room temperature. Two similar plant cultures were held as controls. After 3 days, numerous infections appeared in all inoculated plants, especially on the lower leaves. After 7 days the older leaves were entirely dead, the intermediate leaves showed numerous leaf spots as well as those near the apex. The fungus was readily recovered from typical spots and agreed in every respect with the culture used for inoculation. The culture plants held as control, not inoculated, remained healthy.

SERIES II—OTHER FORAGE AND OIL BEARING GRASSES

Six one-eye cuttings of Napier grass, (*Pennisetum purpureum*) were sterilized for 10 mins. with 1-1000 $HgCl_2$ aqueous solution and without washing, planted in six 4″ pot cultures of autoclaved soil under tall, sterile glass jars. Similar pot cultureswere prepared of six sterilized rhizomes of lemon grass (*Cymbopogon citratus*). Four steam sterilized 4″ pots filled with soil were planted with several cattail millet seeds (*Pennisetum glaucum*) which had been treated with Spergon just before planting. Pots were covered immediately with tall, sterile glass jars after planting. All the above plant cultures were grown under greenhouse conditions for 17 days before inoculation.

A single-spore isolate of the Para grass *Helminthosporium*, grown on sterilized Para grass leaves for 13 days was used for inoculation by preparing a spore suspension thereof in sterile distilled water. Using a sterilized atomizer, the spore suspension was sprayed on the young plants. Two pot cultures of cattail millet (about 8 plants per pot), two pot cultures of lemon grass and three pot cultures of Napier grass were inoculated. The remaining cultures of each grass were kept as controls. In addition to the above, two healthy young shoots of citronella grass (*Cymbopogon nardus*) were thoroughly washed with tap water and then sterile distilled water and one of them sprayed with the Para *Helminthosporium* suspension and the other left as control. Also two healthy shoots of guinea grass (*Panicum maximum*) were washed with water similarly and one of them sprayed with the Para *Helminthosporium* and the other left as control. These shoots were placed separately in tall, sterile glass cylinders with their bases in sterile distilled water and the cylinders plugged with sterile cotton and kept near a window in the laboratory.

RESULTS OF SERIES II

Cattail Millet. After 48 hours, many lesions were noted on the inoculated plants. After 8 days several of the leaf spots had developed into elongated, purplish red spots 5 mms. long × $1\frac{1}{2}$ mms. wide, with irregular margins. Fig. 2, C shows typical leaf lesions after 8 days, some of which are quite elongate. Similar lesions were also noted on the leaf sheaths.

Napier Grass. After 69 hours, many minute eye-spot like lesions were found developing on the inoculated plants. After 8 days, the spots were well developed and after 32 days, some leaves showed lesions 10 mms. × 3 mms. in size with irregular outlines. Fig. 2, B shows typical spots after 8 days.

Lemon Grass. After 8 days, a few very minute incipient spots were noted on one leaf only.

Citronella Grass. After 8 days no infections visible.

Guinea Grass. After 8 days no indications of infection were obtained.

By removing portions of typical leaf spot lesions from cattail millet, Napier grass and lemon grass, sterilizing same superficially with 1-1000 mercuric bichloride solution, washing thoroughly in sterile distilled water and plating the tissues in Petri plates poured with sterile nutrient agar, the Para grass *Helminthosporium* was readily recovered in all instances and agreed in every respect with the culture used for inoculation. None of the control plants of millet, Napier grass or lemon grass showed infections during the period they were held under observation.

SERIES III—SUGAR CANE

Saccharum officinarum

Six four-inch clay pots were filled with soil and autoclaved at 15 lbs. steam pressure for 15 mins. Each was then planted with one single-eye cutting of the noble cane variety D. 74. The cane cuttings were first given the hot water treatment at 52° C. for 20 mins., then dipped in 1-1000 $HgCl_2$ aqueous solution for 10 mins. before planting without washing. Immediately after planting, each pot culture was covered with a large glass sterilized gallon jug which exactly fitted the rim of the pot. These pot cultures were then grown under greenhouse conditions for 14 days before using them for test. Two of the rapid growing plant cultures were then sprayed with an aqueous suspension of spores from a single-spore culture of the Para grass *Helminthosporium* grown for 10 days at room temperature on sterile Para grass leaves. Two pot cultures were kept as controls. One inoculated plant was left in the greenhouse for high temperature incubation, while the other was kept in the laboratory by a window for room temperature incubation.

RESULTS OF SERIES III

Twenty-four hours after inoculation, the sugarcane leaves on the plant in laboratory showed numerous water-soaked minute spots to be visible. After 40 hours, the latter culture showed many small eye-spot like lesions, the centres being red and surrounded by a yellowish halo. Spots appeared both on the blade as well as mid-rib portions of young leaves. Spots were also visible on leaf sheaths and along the spindle of unrolled centre whorl of leaves. Fig. 2, A shows the appearance of typical leaf and leaf-sheath lesions on D. 74 cane after 8 days at room temperature in the laboratory. It was observed that several of the leaf spots were quite elongate and appeared bounded laterally by the parallel leaf veins. In this respect young lesions could hardly be distinguished from those known to be produced by the brown stripe organism *Helminthosporium stenospilum*.

The culture incubated under greenhouse conditions, where the temperature under the jars often reached between 37 and 41° C. during bright sunshine periods, showed several small spots developing after 40 hours, but not nearly as many as in the indoor, laboratory culture in the shade.

Typical leaf spot portions of the cane leaves were sterilized superficially with 1-1000 $HgCl_2$ aqueous solution, washed in sterile distilled water and plated in nutrient agar. In all instances, the same fungus used for inoculation was recovered in pure culture. The control cane plants showed no infections throughout the course of these experiments.

SOME COMPARATIVE STUDIES OF *HELMINTHOSPORIUM SACCHARI* AND THE PARA GRASS *HELMINTHOSPORIUM*

Using the same technique employed for inoculation experiments with Para grass under Series I and sugarcane under Series III above, a culture of *Helminthosporium sacchari* isolated from Cl. 41-223 cane variety was used for inoculating both D. 74 sugarcane and Para grass. After 48 hours under laboratory temperatures, the D. 74 leaves showed numerous infections, some spots extending one-half inch in length. On the other hand, after one week, none of the Para grass leaves became infected with the fungus.

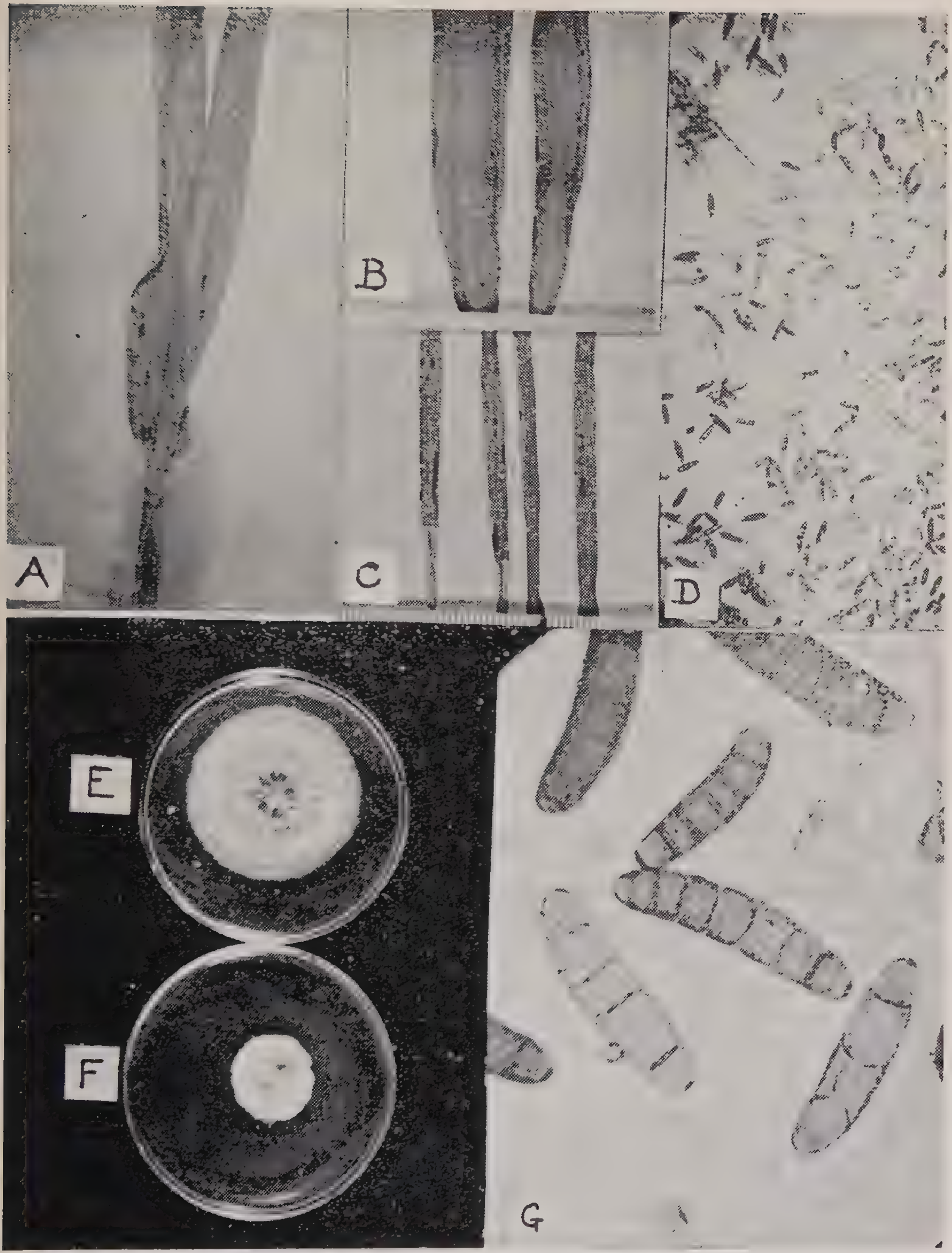

Fig. 2. Typical spots produced after 8 days by spraying pores of *Helminthosporium purpurascens* sp. nov. on A — Sugar Cane leaves and leaf sheaths, B — leaves of Napier grass (Scale divs. = 1 mm.), C—leaves of cattail millet (Scale divs. = 1 mm.). General appearance of spores in artificial culture of *H. purpurascens* sp. nov. D and G. Growth of colonies at 80°F. for 4 days on " Difco " starch cane juice agar, —E—*H. purpurascens* sp. nov., F—*H. sacchari.*

In connection with observations on the growth of *H. sacchari* and the Para grass *Helminthosporium* in nutrient agar cultures, it was noted that the latter apparently made very rapid growth compared with the former and also had certain other distinguishing cultural features. It was decided, therefore, to compare the growth of these two fungi side by side at the same temperature and on the same nutrient medium in too replicated trials. In each trial, ten Petri plates were poured with 15 ml. each of a sterile medium consisting of standard " Difco " starch agar containing 150 ml. cane juice per litre. Five plates were then inoculated in the centres with a small loopful of spores of *H. sacchari* and five plates with a small loopful of spores of the Para grass *Helminthosporium*. The medium was found to have a pH of 5.15.

It was observed after growth of the two series of fungus cultures for 4 days that the *H. sacchari* colonies were dark olivaceous in colour, except for a white border of about 2 mms. This same appearance persisted after 7 days. The Para grass *Helminthosporium* cultures after 4 days , on the other hand, were light olivaceous to almost greenish white in colour with a whitish border 2 mms. deep. After 7 days, the colonies darkened somewhat, so that they could be classed as olivaceous, except for the white border, but definitely not as dark as the colonies of *H. sacchari.*

Table I gives the results of growth measurements of the five Petri plates of each fungus after 90 hours at an average of 80° F. one of the trials. The diameter of the colony in each plate was calculated as the mean of two measurements taken at right angles. Figure 2, E and F show the relative growth and appearance of the Para grass *Helminthosporium* and *H. sacchari* respectively after 4 days at 80° F.

TABLE I

DIFFERENCES IN DIAMETER OF COLONIES OF TWO *HELMINTHOSPORIUMS* IN PETRI PLATE CULTURES OF NUTRIENT AGAR* AT 80°F. FOR 90 HOURS FROM FIVE REPLICATIONS

Fungus		Mean Diameter (cms.)
Para Grass *Helminthosporium*	—	5.33
Helminthosporium sacchari	—	2.85
General Mean	—	4.09
Standard Error of Mean Difference	—	0.4466
Least Significant Difference		
Between Means at 19 : 1	—	1.03
at 99 : 1	—	1.50
" t " factor found =	—	5.55
" t " factor required at 5% point	—	2.306
at 1% point	—	3.360

* Medium consisted of " Difco " starch agar containing 150 ml. cane juice per litre added as supplement.

It is seen that the Para grass *Helminthosporium* grown at 80°F. on the same nutrient agar as *Helminthosporium sacchari*, produced colonies on the average 87% larger in diameter and 50.9% significantly larger in diameter than the latter at the 5% point for significance. In a second trial, using the same number of replications, similar results were secured.

In view of the morphological and physiological differences of the Para grass *Helminthosporium* from those which have been recorded for other species, the fungus is described as a new species and the following name is proposed : *Helminthosporium purpurascens* sp. nov.

Maculae in foliis *Panici purpurascentis* premo sunt subrufae fissurae in forma ovata circumdatae corona flavida ; deinde fiunt fuscae in colore atque centra sunt in colore stramenta. Cum conditiones sint secundae contagro multitudinis, maculae sunt tam multae ut saepe coalescant ad faciendas maculas abnormis formae cum centris coloris stramenti et cum marginibus subrufi purpurei. Conidiophora fuscous sint aut non sint geniculatae, 92.5—330μ × 5.6μ, biseptatae ad pleuroseptatae. Conidia sunt infusci olivarii, 11.1—44.8 × 9.3 — 14.8μ (medium inter maximum et minimum 29.7 × 12.0μ) vulgo 1-6 septatae. Habitat : parasitus in foliis *Panici purpurascentis* Raddi, *Penniseti purpurei* Schumach et *Cymbopogonis citrate* D.C. atque in foliis et foliis-skethiis *Penniseti glauci* (L.) R. Br. et *Sacchari officinari* L.

QUARANTINE CONSIDERATIONS

The discovery of the new disease of sugarcane caused by an undescribed species of *Helminthosporium* previously found associated with leaf spots on Para grass, serves to emphasize the problems of sugarcane quarantine. According to Weintraub (8) Para grass was introduced into the United States. Whether this disease was introduced with the grass is not known, since it could have gained entrance on the other grasses listed by this author as introductions also and which have now been shown to be susceptible *e.g. Pennisetum purpureum*, *Pennisetum glaucum* and *Cymbopogon citratus*. It would seem to be extremely important that pathologists should explore further the occurrence of sugarcane diseases on other graminicolous hosts, including the newly discovered ratoon stunt virus. Pending the acquisition of accurate data on the diseases harboured by various grasses, all of them should be viewed with suspicion and our quarantine laws strengthened accordingly.

SUMMARY

1. A species of *Helminthosporium* commonly found associated with Para grass leaf spots (*Panicum purpurascens* Raddi) in the Florida Everglades, has been proved to be the primary parasite involved. Whether the fungus is the same as one previously reported, but not described from Gainesville, Florida is not

known. The local fungus has been described as a new species with the name *Helminthosporium purpurascens* sp. nov.

2. Para grass *Helminthosporium* has been found to be highly parasitic to leaves and leaf sheaths of sugarcane (*Saccharum officinarum* L.) and cattail millet (*Pannisetum glaucum* (L.) R. Br.) and leaves of Napier grass (*Pennisetum purpureum* Schumach), but only slightly parasitic to leaves of lemon grass (*Cymbopogon citratus* D. C.). Attempts to infect leaves of Guinea grass (*Panicum maximum*) and citronella grass (*Cymbopogon nardus*) gave only negative results.

3. *Helminthosporium sacchari* obtained from sugarcane has been found to be non-infectious to the leaves of Para grass when inoculated thereon, although the same culture was highly infectious to the leaves of sugarcane.

4. Comparative replicated studies of the growth of *Helminthosporium purpurascens* sp. nov. and *Helminthosporium sacchari* (van Breda de Haan) Butler showed that at 80°F. on Petri plates poured with " Difco " starch agar supplemented with sugarcane juice, the two fungi could be readily distinguished by the colours of their colonies and their rates of growth. The former fungus was found to produce colonies in plate cultures with diameters 50.9% significantly larger than the latter at the 5% point for significance for the same period of growth.

5. The leaf lesions produced by *Helminthosporium purpurascens* sp. nov. on sugarcane resemble those produced by the brown stripe organism *Helminthosporium stenospilum*, being typically elongate. Elongate lesions are frequently produced on cattail millet also.

6. Typical disease lesions produced by *Helminthosporium purpurascens* sp. nov. on four of its host plants are described and illustrated. Spores and cultural characters of the fungus are also described and illustrated.

7. The discovery of a new sugarcane disease caused by a fungus parasitic on several other graminicolous hosts has been discussed in relation to quarantine regulations.

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Mr. Kirti Kar then presented the following paper.

Paper

SOME ASPECTS OF CONTROLLING RED ROT IN UTTAR PRADESH

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Uttar Pradesh possesses about half of the total cane acreage in Indian Union which contains one-third of the global acreage of cane. Besides an important role as a cash crop in the agricultural economy, sugarcane supports the second important industry of India. Red rot is the most serious disease and an important contributory cause of low yields in many localities. Although Butler (1918) considered it to be a limiting factor, its destructive capacity was fully realised by different interests connected with the industry only in 1938-40 when Co. 213 was completely wiped out.

Divergent views have been held about the role of setts as a source of infection. Butler and Hafiz Khan (1913) held that the setts were the sole carriers of infection while Edgerton (1911) thought that the mother setts do not play any part. The studies of affected samples in 1938-40 revealed that none of these views was tenable. Infection from the mother setts as well as secondary infection were found in the diseased specimens. The authors (1954) have found that red rot debris in the soil, and inoculum in irrigation water are as important in dissemination of disease as the infected setts. In highly susceptible varieties like Co. K. 26, Co. S. 430, 36.6 and 42.6 percent infection resulted respectively by the application of red rot debris to soil and spores through irrigation water. Chona (1950) has also arrived at similar findings.

The two important observations of the epidemic of 1938-40, were the appearance of a new and virulent strain of red rot (1942) and differences in varietal resistance to the disease. Co. 421 and Co. 312 withstood the disease and were subsequently used for replacing Co. 213. The varietal resistance tests were hereafter considered necessary before the release of the varieties.

Within three years of this epidemic four varieties resistant to red rot e.g. Co. 453, Co. 527, Co. S. 76 and Co. S. 109 were released for cultivation. The problem of the disease appeared to have abated till the complacency of the cultivator, who was depending solely on the resistance of varieties, was shaken up in 1946-47 when Co. 312 became a victim to red rot. In this epidemic, it was observed that although Co. 312 suffered in a large number of localities, progressive and more careful growers continued to grow satisfactory crop of this variety. This clearly indicated the importance of cultural methods and risks involved in sole dependence on the varietal resistance for saving the crop from red rot. Another important aspect of the epidemic was that the Western Range was almost free from the infection, whereas in the former epidemic no such distinction could be made. This was a pointer for differences in the environmental conditions of this area as compared to those in the Central and Eastern parts of Uttar Pradesh. This information proved to be very valuable in so far as it made possible in this tract, the release of varieties like Co. S. 245 and Co. S. 321 possessing moderate resistance to red rot.

The study of parasitic flora during this epidemic and the subsequent one in 1950, when Co. 453 deteriorated, showed that the appearance of new strains had played an important role. The recent discovery of the perfect stage of the causal parasite by Chona (1953) lends further support to the possibility of multiplication of physiologic forms.

Unlike other crops where each generation begins from sexually produced seed, the cane crop is propagated vegetatively by stem. This provides a scope for effects of environments being reflected in the succeeding generation. An experiment was conducted at Shahjahanpur to study the resistance of crop to red rot grown with planting material from four different environments enumerated below :—

(1) Maximum yield trial adequately manured to supply all plant requisites and given ideal interculture.

(2) Crop showing yellowing of leaves.

(3) Crop with diseased clumps. Setts from apparently healthy canes were used for planting.

(4) Unmanured fields. The crop was, however, disease free. The crop grown with this seed was treated as control.

Hundred canes of each treatment were inoculated by ' plug ' method with a virulent culture of red rot when the crop was six months old. About four months after inoculations, the lesion lengths were measured. The observations are given below :—

TABLE I

SHOWING EFFECT OF ENVIRONMENT ON RESISTANCE OF SUGARCANE TO RED ROT

Variety	Treatment of seed crop	Average lesion spread in cms.	Average cane height
Co. 453	Maximum yield crop	30.5	8′—9″
	Diseased crop	48.9	6′—9″
	Crop showing yellowing of leaves	38.6	6′—4″
	Control	39.3	6′—11″
Co. 312	Maximum yield crop	81.9	7′—6″
	Diseased crop	108.4	6′—0″
	Crop showing yellowing of leaves	97.7	6′—1″
	Control	94.8	6′—9″
	Standard error (lesion spread)		±8.3 cms.

The above data clearly indicates the effect of environment of planting material on the resistance of crop to red rot. It throws important light on the phenomenon of deterioration of varieties and cumulative effect of indifferent cultivation year after year. These results clearly indicate the necessity of selecting planting material from disease free localities. If necessary precautions are exercised at the first appearance of symptoms of deterioration, varieties could be easily saved. When, however, the emphasis is shifted from suitable cultural practices to varietal replacement the process of deterioration is hastened.

A trial was conducted to study the differences in resistance of plant and ratoon crops of different varieties to red rot. The comparative data based on average lesion length of hundred canes inoculated by ' plug ' method is given below.

TABLE II

SHOWING EFFECT OF RATOONING ON SUSCEPTIBILITY TO RED ROT

Variety	Average lesion length in the plant crop in cms.	Average lesion in the 1st year ratoon crop in cms.
S. 119/52	85.2	130.7
Co. 737	44.6	125.1
Co. S. 463	120.3	127.6
Co. S. 470	74.7	133.3
Co. 313	45.9	78.8
Co. S. 513	77.4	64.9
Co. 705	74.9	116.0
Co. S. 512	69.2	87.5
Co. 453	47.2	114.3
S. 261/52	48.3	64.7
S. 117/52	73.5	115.6
S. 164/52	56.4	81.3
B. O. 11	49.0	61.3
Co. S. 514	143.9	137.9
Co. 622	98.6	94.1

It is evident that first year ratoons are generally more susceptible to red rot than the plant crops of the same variety. Similar studies on successive ratoons are expected to yield useful data. The above results indicate the necessity of discouraging ratooning in localities where red rot begins to assume epidemic proportions.

Experiments were conducted to study the possibility of saving the crop from infection at different stages. Trials were laid out to study the possibility of saving sugarcane from red rot infection through contaminated soil, debris of red rot affected canes and spores in irrigation water by treating setts with fungicides for ten minutes prior to sowing.

In a trial at Shahjahanpur, treated setts of Co. 331 were sown in fields to which contaminated soil and debris of red rot affected canes had been applied.

The summarised observations at the time of harvest regarding the incidence of red rot are given below.

TABLE III

SHOWING PERCENTAGE OF RED ROT AFFECTED CANES

Fungicides	Strength of fungicides	Percentage of diseased canes
Agrosan G. N.	10 lbs. to 100 gallons of water	42.5
Fernasul	20 pints to 100 gallons of water	47.7
Sulphur	2 gms. to 100 c.c. of water	54.8
Perenox	15 lbs. to 100 gallons of water	56.2
Spersul	3 lbs. to 100 gallons of water	52.5
Merc. chloride	1 gm. to 1000 c.c. of water	57.9
Control	Ordinary water	47.5

Standard error ± 7.9 cms.

None of the treatments proved effective in controlling red rot.

In another trial conducted simultaneously at Shahjahanpur and Gorakhpur with different varieties, infection was provided through debris of affected canes and application of red rot spores through irrigation water. The observations regarding the incidence of the disease were made at regular intervals. The fungicides used for treatment of setts and data of red rot incidence at the time of harvest are given below.

TABLE IV

SHOWING PERCENTAGE OF RED ROT AFFECTED CLUMPS IN DIFFERENT VARIETIES AT SHAHJAHANPUR

Treatment	Strength of fungicide	Percentage of diseased clumps		
		Co. 622	Co.S. 443	Co.S. 430
Aretan	1 lb. to 20 gallons of water	27.3	Nil	45.3
Cuprokylt	5 lbs. to 100 ,, of water	9.3	Nil	53.8
Perenox	15 lbs. to 100 ,, ,,	21.3	Nil	58.0
Merc. chloride	1 gm. to 1000 c.c. of water	15.2	Nil	66.0
Control	Ordinary water	20.2	Nil	55.3

TABLE V

SHOWING PERCENTAGE OF RED ROT AFFECTED CLUMPS IN DIFFERENT VARIETIES AT GORAKHPUR

Treatments	Strength of fungicide	Percentage of diseased clumps		
		Co.S. 430	Co.S. 416	Co.S. 470
Aretan	1 lb. to 20 gallons of water	26.3	Nil	11.8
Agrosan G.N.	1 lb. " " "	37.1	Nil	8.0
Perenox	15 lbs. to 100 " "	37.2	Nil	9.1
Spersul	3 lbs. to 100 " "	24.2	Nil	25.0
Control	Ordinary water	37.7	Nil	13.7

It is apparent from the above results that the fungicidal film on the setts resulting from their being steeped prior to sowing does not provide protection against infection through contaminated soil and water carrying spores. In the control of pineapple disease, Evans (1947) observed dipping of setts in organo mercurial compounds very useful, but in case of red rot where the disease attacks the crop at all stages, fungicidal treatment of setts does not prove effective.

The use of systemic fungicides has given useful results e.g., 2- (4-Morpholenyl) ethyl phenyl ketone gave significant results in controlling bacterial blight of beans and Cyclopentenyl butyldithiocarbamate in case of *Fusarum* wilt of tomatoes. To try this phenomenon on sugarcane, spraying of leaves with three fungicides was done to see if it has any systemic effect, by way of inducing resistance to red rot. It was done thrice during the growing season between June and August. The inoculations with a virulent culture of red rot were done towards the end of August and lesion lengths measured four months later. About one hundred canes were inoculated for each treatment. The results are summarised below.

TABLE VI

SHOWING SYSTEMIC ACTION OF FUNGICIDES ON RESISTANCE TO RED ROT

Treatments	Strength of the chemical	Lesion length in cms.	
		Co. 312	Co. 453
Hydroquinone	4 ozs. in 10 gallons of water	61.8	38.5
Perenox	2 pints in 10 gallons of water	74.2	38.2
Lime sulphur	4 ozs. in 10 gallons of water	77.8	40.5
Control	Ordinary water	75.2	38.2

Standard error ± 5.8 cms.

There were no significant differences between the treatment alqtough the effect of spraying with hydroquinone in case of Co. 312 was indicative.

Red rot lesions on the leaf mid-rib are an important source of inoculum, During the monsoons spores from acervuli on these mid-rib lesions are washed down into the leaf sheath where they find favourable conditions for germination and infection of the stem through the nodal region. The possibility of controlling red rot by reducing the occurrence of mid-rib lesions of the leaves through spraying of fungicides was suggested by Mr. K. L. Khanna in his presidential address to the Development Section of the Second Biennial Conference of Sugarcane Research and Development Workers in Indian Union. Experiments to study this possibility were conducted at Gola, Biswan and Faizabad where red rot frequently occurs. Dithane, Coppesan, Perenox and Blitox were sprayed thrice between July and September at intervals of four to six weeks. The dosage was two pounds of fungicide in one hundred gallons of water. One hundred to one hundred and fifty gallons of solution was needed per acre for each spraying. The observations to judge the efficacy of operations were made in January and February in the following manner. For each treatment hundred canes were examined by taking one from each stool picked up at random. In each case the number of healthy fully opened leaves and those showing mid-rib lesions were recorded to obtain the percentage of affected leaves. To determine the average lengths of mid-rib lesions, a sample of four hundred leaves was collected by picking one from each stool taken at random. Out of this sample length of mid-rib lesions of hundred leaves picked up at random was measured. The observations are given below :—

TABLE VII

SHOWING RED ROT INCIDENCE ON MID-RIB OF SUGARCANE LEAVES

Zone	Variety	Plant/ratoon	Treatment	Percentage of leaves showing mid-rib lesions	Length of the mid-rib lesions
Biswan	Co. 453	Ratoon	Coppesan	11.3	31.9
,,	,,	,,	Control	12.3	65.1
,,	,,	Plant	Coppesan	10.1	37.9
,,	,,	,,	Control	15.2	48.3
Gola	,,	Ratoon	Perenox	12.3	45.4
,,	,,	,,	Control	17.5	66.5
,,	,,	,,	Dithane	11.6	30.2
,,	,,	,,	Control	17.6	66.5
Faizabad	Co. 617	Plant	Blitox	34.8	23.5
,,	,,	,,	Dithane	35.2	25.2
,,	,,	,,	Control	39.3	60.6

The above data gives some indications of the beneficial effects of spraying by Blitox and Dithane. Detailed studies based on extensive trials will be necessary before any conclusions about the usefulness of this method can be drawn.

DISCUSSION

The use of resistant varieties, which appeared to be the panacea for the disease fifteen years back, has turned-out to be a measure with limitations since the resistance of varieties breaks down after a certain period due to the appearance of new physiologic forms of the parasite in nature. The experience of cane breeder has been that only a small percentage of agronomically promising selections possess high degree of resistance to red rot. The treatment of setts with chemicals has proved of little value as a safeguard against red rot infection.

The possibilities of using systemic fungicides and spraying against secondary infection need detailed studies. In event of their proving effective in controlling red rot, their economic and practical aspect will have to be examined before being recommended to the cultivator.

The care that the cane crop receives after a variety is released to the cultivator is by far the most important factor in determining its period of utility. It is by proper seed selection and sanitary conditions of cultivation that not only the varieties can be saved from deterioration but moderately resistant varieties can be safely grown.

In the present context, the use of resistant varieties appears to be the most important measure for controlling the disease. The performance of these varieties will, however, depend to a great extent on the attention that they receive. If success is obtained in substantially mitigating the inoculum of the disease in nature, we would have obtained an environment in which the existing varieties will be able to flourish and those which possess moderate resistance to the disease, would also do well. This would make the work of the breeder easier. Success in this direction has been obtained by some leading countries through intensive propaganda and legislation. King (1954) has aptly remarked that the sugarcane industry can rid itself of the threat of cane diseases whenever the resolution is made to attack the problem with appropriate counter measures. Such measures have to be applied by concerted action of the whole industry backed by legislative authority.

SUMMARY

(1) Red rot is one of the most important contributory causes of low yields of sugarcane and its destructive nature was fully realised in 1938-40 after a severe red rot epidemic.

(2) Butler's view ' clean setts and no disease ' does not hold good as other factors are also playing equally important part in spread of the disease.

(3) The differences in varietal resistance to red rot emphasised the necessity of testing the resistance of varieties before their release for cultivation.

(4) The epidemic of 1946-47 did not cause as extensive damage as of 1938-40. The changes in parasitic flora were an important cause for the epidemic.

(5) The sole dependence on resistant varieties has proved to be illusory due to constant changes in the parasitic flora.

(6) The environmental conditions play an important role in infection and spread of red rot.

(7) The progressive and careful farmers can grow healthy crops even of such varieties which do not possess a high degree of resistance to red rot.

(8) The crop grown with planting material from healthy and well manured fields is comparatively more resistant to red rot.

(9) First year ratoon does not retain as much resistance to red rot as the plant crop of the same varieties.

(10) it has been established by experimentation that the fungicidal film on the setts resulting from their being steeped prior to showing provide little protection against infection through soil and irrigation water.

(11) No conclusive results have yet been obtained about systemic action of fungicides through spraying of leaves. Hydroquinone has, however, given some indication of its usefulness in this respect.

(12) To reduce red rot infection on mid-rib of leaves, spraying by Dithane and Blitox have given encouraging results.

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Mr. K. V. Srinivasan then presented the following paper.

Paper

A PRELIMINARY STUDY OF THE REACTION OF *SACCHARUM SPONTANEUM* VARIANTS TO RED ROT, SMUT, RUST AND MOSAIC

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INTRODUCTION

Resistant varieties of sugarcane are important means of control against several diseases like red rot, *Pythium* root rot, smut, downy mildew, eye spot, leaf scald, gumming, mosaic, chlorotic streak, Fiji disease, sereh, ratoon stunting, besides minor diseases like Pokkah Boeng and Brown spot. Fortunately diseases like downy mildew, leaf scald, gumming, sereh and Fiji disease do not occur in India. The most important diseases prevailing at present are red rot [*Glomerella tucumanensis* (Speg.) Arx and Muller] and smut (*Ustilago scitaminea* Syd.), the former in North India and the latter in the South. Epiphytotics of red rot have been responsible for a succession of varieties in the main sugarcane tracts. Instances are the epiphytotics of 1938-39 and 1946-47. During the former Co. 213, the most popular and universal cane in northern India had to be replaced and during the latter varieties like Co. 312 and *Mamchuah* were affected. Smut is a menace and resistant varieties appear to offer the one means of reducing the heavy cost at present incurred in localising *foci* of infection. Rust [*Puccinia kuehnii* (Krueg.) Butl.] has been recorded in recent times in Bombay (Chona and Munjal, 1950). It has appeared on Co. 876 at Nellikuppam in the South (Chenulu, 1954). Subsequently the senior author has observed it on Co. 928 in the same locality. It is also known to occur on several varieties in Hyderabad. It is evident that the disease is spreading and is likely to become serious in the near future. Mosaic is ubiquitous in its occurrence, but fortunately the loss caused by it is low at present in India. A matter for concern however in recent years has been the increasing number of varieties affected with mosaic. Varieties like Co. 214 which have held out for a number of years are no longer immune. The possibility cannot be overlooked of the disease taking a more destructive turn in the future on account of the appearance of new strains of the virus by mutation or introduction and the breaking down of the tolerance of Indian varieties of sugarcane. Since rust and mosaic are thus dangerous diseases already present in the country it is desirable to know the resistance potential available in our breeding stocks.

The wild species *Saccharum spontaneum* L. has been sought as a genetic source of resistance to several diseases like Sereh, *Pythium* root rot, gumming, red rot and mosaic (Abbott, 1953). A large collection of variants of

S. spontaneum has been assembled in the Spontaneum Expedition Scheme at this Institute with the object of studying them and evaluating their breeding value (Panje, 1953). The collections from within the Indian Union number over three hundred. Some forms have been imported covering the distributional area of the species. It is known that different variants of *S. spontaneum* differ in their resistance to any given disease. With the object, ultimately, of assessing the resistance of the individual variants available in the collection to each of the four diseases, preliminary observations based on artificial inoculations in the case of red rot and smut and field incidence in the case of rust and mosaic have been recorded and are presented in this paper.

REVIEW OF LITERATURE

Abbott (1938) found most of the varieties of *S. officinarum* 'susceptible to highly susceptible ' to red rot, as also those of *S. sinense* and *S. robustum*. With the exception of but one form from Formosa varieties of *S. spontaneum* were moderately resistant. He concluded from a study of the lineage of the resistant seedlings produced at Canal Point that some form of S. *spontaneum* was the probable source of their resistance. Chona (1954) observed that ' spontaneums ' proved to be highly resistant to red rot in India while the noble canes were susceptible.

Work on the assessment of resistance of sugarcane varieties to smut has been carried out in India by Chona (1943) and by Dutt *et al* (1951). They observed that the thin Indian canes (S. *Barberi*) were generally susceptible while the thick 'Ponda' canes(*S. officinarum*) were resistant to the disease. Chona and Gattani (1950) recorded that the smut on *Saccharum spontaneum* was capable of infecting sugarcane and expressed the fear that *S. spontaneum* might be a source of infection of cultivated varieties.

Though Butler (1918) recorded rust on *S. spontaneum* and other species of *Saccharum* (which have since been included in other genera viz., *Erianthus*, *Sclerostachya* and *Narenga* (Dutt and Rao, 1951), he found it difficult to believe that Indian sugarcane was everywhere immune. Little work has been reported on this disease. Patel *et al* (1950) reported rust on Co. 475 in the Deccan canal tract of the State of Bombay and described a new species, *Puccinia sacchari*. However, Chona and Munjal (1950) who also found the same variety affected in the same area identified their collection as *P. kuehnii*. They also recorded the interesting observation that specimens of rust on *S. officinarum* had been collected in 1919 from Almora and in 1926 from Pusa thus substantiating Butler's belief.

Dutt *et al* (1936) found that varieties with *S. spontaneum* in their composition like Co. 214 and Co. 335 were resistant to mosaic while those which were not derived from *S. spontaneum* like Co. 223, Co. 241 and Co. 287 were susceptible. Stevenson (1943) expressed the opinion that the genes responsible for immunity from mosaic and sereh disease were carried by the chromosomes of *S. spontaneum*. From a study of successive ‘nobilizations’ of the ‘blood line’ of the immune Kassoer, a natural hybrid between Black Cheribon and *S. spontaneum* (Glagah), he considered that resistance to mosaic was a polygenic character correlated with the number of *S. spontaneum* chromosomes present. Most of the varieties of *S. spontaneum* tested for mosaic resistance in the United States were immune and only a few (those from Turkestan) developed a trace of infection (Summers *et al*, 1948). With the availability of a number of parent varieties with a high degree of resistance to mosaic and the development of a technique for the elimination of susceptible seedlings at a very early stage of their rearing, it has been an easy task to evolve varieties resistant to mosaic (Abbott and Summers, 1951).

MATERIALS AND METHODS

For determining resistance to red rot the variants of *S. spontaneum* were raised in rows ten feet long and the plants were inoculated when they were about eight months old. The strain of *Glomerella tucumanensis* used was the virulent isolate No. 244 kindly supplied by Dr. B. L. Chona of the Indian Agricultural Research Institute, New Delhi. The method of inoculation was that described by Chona (1954). From 25 to 50 stalks were inoculated in each case. The stalks were cut after three months, split and the length of the red rot lesion measured. Disease ratings were based on the average ‘effective lesion length’ in the case of each variant. Co. 213 a highly susceptible variety of sugarcane was used as a standard for comparison.

For the experiments on smut-resistance chlamydospores of *Ustilago scitaminea* were collected from smutted crops of Co. 419 in the vicinity of Coimbatore. The material was dried in the shade and stored in paper envelopes. Viability was tested and only material showing not less than 95% germination was used. A heavy spore suspension was obtained by stirring eight ounces of spores into ten gallons of water. Setts or slips from healthy clumps of the variants under test were steeped in the suspension for 30 minutes, taken out, drained and immediately planted in furrows. Twenty 3-budded setts or slips were planted in each case. Smut whips as and when they appeared on the inoculated plants were carefully removed. The affected clumps were then uprooted and destroyed.

Periodical observations were made of the appearance of rust on the different variants in the field. Natural incidence was heavy. Germination of urediospores was determined periodically by floating them on drops of tap water and incubating the slides inside moist chambers at laboratory temperatures.

The incidence of mosaic in the field was periodically observed. The leaves of the spindle and the young fully unfolded leaves were carefully examined for the symptoms.

OBSERVATIONS

RED ROT

Since 1950* one hundred and fifty eight variants have been tested for their resistance to red rot. Their reaction is set out in Table I. The large majority of variants were resistant. A few like S.E.S. 71, 74B, 106B, 297B, 365, Egypt, thick gigas (Sumatra) and Turkey showed a susceptible reaction. Some like S.E.S. 74B, 87A, 88C and 91 gave a variable reaction, susceptible in one year and resistant in another. This would indicate the possibility of the environment playing a part in determining their reaction. However these variants as also the ones recorded as susceptible should be considered to be undesirable from the point of view of their utilisation in commercial breeding as they have exhibited susceptibility under certain conditions.

TABLE I

REACTION TO RED ROT OF *S. SPONTANEUM* VARIANTS

Name of the variety	Reaction/ No. of years tested	Name of the variety	Reaction/ No. of years tested	Name of the variety	Reaction/ No. of years tested
Peninsular India					
S.E.S.1	2R+MR/3	S.E.S. 69	R/1	S.E.S. 96B	MR/1
,, 2	2R/2	,, 70	2MR/2	,, 96C	R/1
,, 4 A	3R/3	,, 71	S/1	,, 98A	MR/1
,, 4 B	R/1	,, 73	2R/2	,, 100A	3R/3
,, 6	R/1	,, 74A	R/1	,, 102	R/1
,, 8	MR+R/2	,, 74B	R+2S/3	,, 106A	3MR+R/4
,, 11	2R+MR/3	,, 76	2MR/2	,, 106B	S/1
,, 13	3R/3	,, 77	MR+R/2	,, 108A	MR+R/2
,, 14	3R/3	,, 78	R+MR/2	,, 109	R/1
,, 15	MR+R/2	,, 80A	R+MR/2	,, 110A	4R/4
,, 21	2R/2	,, 80B	R+MR/2	,, 113A	3R/3
,, 24	R/1	,, 81	2R/2	,, 113B	MR/1
,, 28	2R/2	,, 83	2MR/2	,, 114	MR/1
,, 29	R/1	,, 84A	4R/4	,, 115A	R/1
,, 31	3R/3	,, 84B	2MR+2R/4	,, 115B	MR/1
,, 32A	2R/2	,, 85A	2R/2	,, 116A	R/1
,, 32B	MR+R/2	,, 85B	R+MR/2	,, 117	R/1
,, 34	2MR/2	,, 87A	R+MR+S/3	,, 118B	R/1
,, 38	2R/2	,, 87B	MR/1	,, 119	MR/1
,, 39	2R/2	,, 88B	R+MR/2	,, 120B	R/1
,, 44A	R/1	,, 88C	MR+MS/2	,, 121A	R/1
,, 45	3R/3	,, 90	3MR+R/4	,, 121B	MR/1
,, 49	2R+MR/3	,, 91	2MR+S/3	,, 124	MR/1
,, 50	MR+R/2	,, 92	MR+R/2	,, 125A	R/1
,, 60	2R/2	,, 94	MR/1	,, 125B	R/1
,, 66	3R/3	,, 96A	R/1	,, 128	R/1

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* Data of reaction of some of the variants to red rot and smut collected by other members of the staff of this Institute prior to 1952 have also been utilised for this study and we are grateful for the same.

TABLE I—(Contd.)

Name of the variety	Reaction/ No. of years tested	Name of the variety	Reaction/ No. of years tested	Name of the variety	Reaction/ No. of years tested
S.E.S. 129A	MR/1	S.E.S. 161A	R/1	G. 3010	MR/1
,, 129B	R/1	S.H. 148	MS/1	(Uganda)	
,, 129C	MR/1	(Thick Gigas		,, 270	R/1
,, 131	R/1	Sumatra)		,, 294	R/1
,, 132B	R/1	S.H. 641	MS/1	*Assam*	
,, 135	MR/1	(Turkey 111)		S.E.S. 297A	MR/1
,, 137A	R/1	,, 179Bii	R/1	,, 297B	S/1
,, 140	MR/1	,, 182	3R+MR/4	,, 299	R/1
,, 141B	R/1	*Indo-Gangetic Plain*		,, 304	2MR/2
,, 144	R/1	S.E.S. 186	2MR+2R/4	,, 317	R/1
,, 145	R/1	,, 188A	MR/1	,, 320	2R/2
,, 146	R/1	,, 188B	R/1	,, 323	MR/1
,, 147A	MR+2R/3	,, 189	4R/4	,, 326	R/1
,, 147B	2R/2	,, 191	2R/2	,, 327	R+MR/2
,, 148	R/1	,, 194	R/1	,, 334	MR+R/2
,, 150	R/1	,, 196	R/1	,, 335	R/1
,, 151A	R/1	,, 197A	2R/2	,, 337A	MR+R/2
,, 151B	MR/1	,, 199B	MR/1	,, 337B	2R/2
,, 152	R/1	,, 203	R/1	,, 340	R/1
,, 161B	R/1	,, 205A	3R/3	,, 341	R/1
,, 165	R/1	,, 205B	3R/3	*Exotic—Nepal*	
,, 168	R/1	,, 208	2R/2	S.E.S. 365	S/1
,, 179Bi	R/1	,, 210	R/1	(var. Nepalensis)	
,, 239	2R/2	,, 214	R/1	S.E.S. 370	R/1
,, 243	MR+R/2	,, 217	R/1	28 N.G. 292	MR/1
,, 244	R/1	,, 220	2R/2	S.S Egypt	MS/1
,, 325	R/1	,, 226	R/1	(S.H. 546—Egypt)	
Orissa		,, 231	3R/3	G. 3011	R/1
S.E.S. 154B	4R/4	,, 234	2R/2	(Uganda)	
,, 158	R/1	G. 3009	R/1	S.H. 424	R/1
,, 160B	R/1	(Uganda)		(Djatiroto)	

R = Resistant ; MR = Moderately resistant ; MS = Moderately susceptible ; S = Susceptible.

Note. The number in the numerator indicates the number of years the reaction was obtained.

Eight of the variants are under progeny studies on account of the promise they hold by virtue of their vigour, high sucrose content, tolerance to salinity etc. (Panje 1953). The selfed progeny of four of these variants were inoculated with cultures of *G. tucumanensis*. All the four parents showed a resistant reaction. Of the 15 seedlings from S.E.S. 45 three were moderately resistant and the rest were resistant. All the 41 seedlings of S.E.S. 239 were resistant. Of 15 seedlings from S.H. 424 (Djatiroto, Java) two were susceptible and the rest resistant. All the five seedlings of S.E.S. 186 were resistant. In three of the four cases the number of seedlings is rather low for drawing conclusions on the inheritance of resistance to red rot.

SMUT

Upto the end of 1954 two hundred and seventy three variants have been subjected to inoculation tests with sugarcane smut. The following 28 variants alone got infected and developed smut whips.

Peninsular India : S.E.S. Nos. 11, 38, 50, 69, 70, 78, 83, 84A, 85B, 90, 91, 92, 93, 113A, 116B, and 144.

North India : S.E.S. Nos. 205A, 208, 239, 270, 304, 320, 323, 326, 327 and 341.

The percentage of infection in the variants varied from 10 to 100. One variant from Manipur S.E.S. 341 was highly susceptible, developing smut whips within eight weeks after planting and showing heavy infection within four to five months of planting.

RUST

As stated already the observations were confined to records of field incidence. The disease occurred mostly from October to January. A large number of variants were affected. In general only the leaf blades showed the rust but in some variants the leaf sheaths and the stems also bore the pustules. The sori appeared on purple, elongate spots. Only the uredia were encountered. Urediosori were elongate, generally hypophyllous, in some variants amphigenous ; urediospores oblong to subglobose, wall echinulate, often thickened

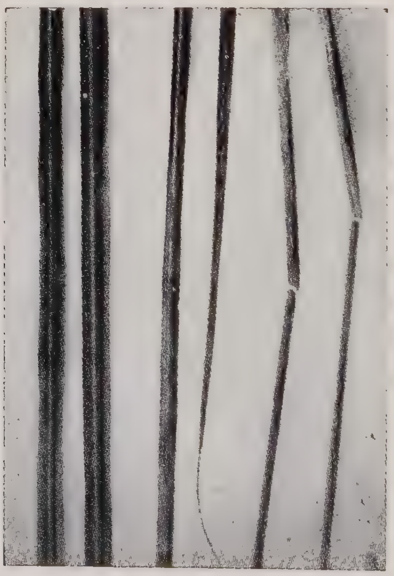

Fig. 1. Rust on *S. spontaneum*
Lesions on leaf sheath and lamina.

uniformly all round or at the apex alone, 30.6-57.8 × 20.4-37.4μ, with three to five equatorially distributed germ pores ; paraphyses peripheral, clavate to capitate, 28-41 × 12-21μ. The characters of the uredial stage are in agreement with those of *Puccinia kuehnii* (Krueg.) Butler (Butler 1918).

The urediospores retained their viability at laboratory temperature upto five weeks during the months of October to January. Collections made in February rapidly lost their viability when stored at laboratory temperature.

The rust affected a few variants in July to September and the number rapidly

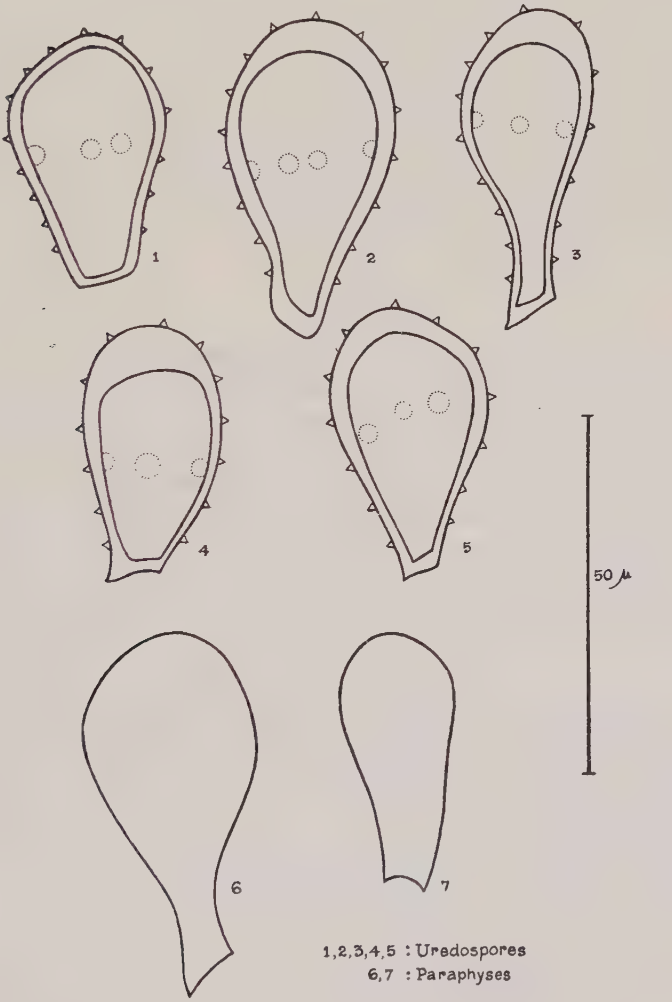
PUCCINIA KUEHNII ON S. SPONTANEUM

Fig I

increased from October to January after which there was a sharp fall. The disease was absent upto mid-June after which one or two variants showed infection. The occurrence of rust appeared to be correlated with temperature.

Indian variants showing rust infection on leaves only consisted of six variants with wiry leaves, sixty five with narrow leaves and sixteen variants with leaves of medium width. Among exotic forms showing this class of infection were four with wiry type of leaves (viz., S.H. 642 and 643 from West Pakistan and G. 1690 and G. 2663 from the U.S.S.R.), and four with narrow leaves (viz., S.H. 361 from Mauritius, *S. spontaneum* var. *aegyptiacum*, S.H. 546 from Egypt and S.H. 639 from Turkey).

Indian variants showing infection of leaves, sheaths and stem consisted of two wiry leaved, fifteen narrow leaved, six medium leaved and one broad leaved variant. Foreign variants were two narrow leaved forms from Turkey (S.H. 640 and 641) and one broad leaved form from Algiers (S.H. 577).

While a large number of narrow and wiry leaved variants were affected few broad leaved ones exhibited the attack. Within the Indian Union the variants from the Assam region with the exception of two (S.E.S. 323 and 340) were not affected. Several from the Middle East, U.S.S.R. and Africa were affected but none from the Indonesian region.

MOSAIC

The pattern of leaf symptoms varied from yellow mottle to faint stippling. On sugarcane under Coimbatore conditions rapid spread of the disease occurs during the months of May to August and little active transmission is noticed during the months of December and January. There is also masking of symptoms during these latter months on some varieties. During the summer months mosaic appears on such a scale that few varieties of sugarcane escape. Although transmission experiments under controlled conditions will give a truer picture of resistance, the record of natural incidence during the period when heavy secondary infection occurs may be considered to be a fairly reliable guide to indicate at least the susceptibility of individual variants though not the resistance of others.

The following variants exhibited mosaic symptoms during 1954 :

Peninsular India : S.E.S. 2, 28, 94, 137B and 152.
Assam : S.E.S. 320, 322, 337A, 337B and 341.
Exotic forms :
S.E.S. 370 (Nepal) ;
28 N.G. 101 and 28 NG 292 (New Guinea) ;
S.H. 687 (Glagah ?, China) ;
S.H. 328 (Tabongo, Northern Celebes)
and S.H. 424 (Djatiroto, Java).

DISCUSSION

Hitherto only two variants of *S. spontaneum* have been used in commercial cane breeding, viz., Coimbatore local and Glagah (Java). The collection of a large number of variants in the Spontaneum Expedition Scheme has made available a wide choice of parental material. It is to be expected that these variants which have been collected from different climatic and ecological regions will also differ in their genetic make up and reaction to various diseases. The need for caution in the choice of genetic stocks from the point of view of disease susceptibility needs no emphasis.

Abbott (1938) recorded a number of variants from India, East Indies and Formosa to be moderately resistant to red rot while one Formosan form was very susceptible. Chona (1954) found the Coimbatore form, S. s. Burma and S. s. Java to be highly resistant. A large number have been studied at this Institute so far and the existence of susceptibility in a few has been revealed. These have been tested so far against one highly virulent isolate of *Glomerella tucumanensis*. As in Louisiana the sudden appearance of new virulent strains has been recorded in India (Chona and Padwick, 1942). The recent breakdown in the resistance of varieties like Co. 453 in Bihar has also been attributed to the appearance of new strains of the causal organism (Rafay, 1950). The possibility exists of differences in the susceptibility of various forms of *S. spontaneum* to different strains of the pathogen. The need for testing the collection with other strains of the disease agent becomes apparent.

Lee and Medella (1931) attributed the susceptibility to smut of P.O.J. 2878 to its *S. spontaneum* progenitor. The general view has been to regard the species *S. spontaneum* as being liable to impart susceptibility to smut (Abbott, 1953). Of 273 variants tested at this Institute only 10% have so far taken infection. Though some like S.E.S. 341 have shown high susceptibility it is clear that considerable variation exists. It is within the bounds of possibility that several of the large majority that did not take infection in the present study are immune and in that case it should not be a difficult task to select out variants that do not transmit susceptibility to smut to their progeny.

The preliminary observations on the incidence of rust recorded here have shown that a large number of variants are susceptible in varying degrees. The broad indication would appear to be that *S. spontaneum* is not promising from the point of view of rust resistance. However, the fact should be considered of some significance that although rust appeared in a virulent form and many variants were infected a number of broad leaved forms particularly those from the regions of Assam and Indonesia were not affected. It is proposed to test these variants by inoculation under controlled conditions and see if they will really prove to be resistant.

Variation in mosaic susceptibility of varieties of sugarcane with parentages of different forms of *S. spontaneum* has been noticed previously. Inniss (1944) reported from Barbados that while the ' local ' form of *S. spontaneum* when crossed with 'Chunnee' nobilizations appeared to produce susceptible seedlings, in the Glagah line there was an almost 2:1 ratio in favour of resistance. Summers *et al* (1948) found, on extensive observations of natural incidence, practically all the members of the collections of *S. spontaneum* maintained at Houma, La. and Cairo, Ga. in the United States free from mosaic. At Coimbatore some variants have exhibited mosaic symptoms under conditions of natural incidence. The strains of the mosaic virus differ in different countries. Chona (1950) differentiated three strains in India chiefly by their thermal inactivation point. Sugarcane varieties found resistant in one part of the country have proved susceptible in other parts (Dutt *et al* 1936). Other evidence points to a change in the strains prevalent in the country in recent years. Some varieties which remained immune till recently are now affected (Dutt and Hussainy, 1951). There is need to study more intensively the occurrence and distribution of the strains of mosaic in the country and the susceptibility of *S. spontaneum* variants to the different strains before choice of parents for breeding against mosaic is made.

SUMMARY

Of 158 variants of *S. spontaneum* tested for resistance to red rot by the method developed in India the majority gave a resistant reaction, 8 were susceptible and 4 were variable. The selfed progenies of 4 variants were tested. The progeny of S.E.S. 239 was resistant, while that of S.E.S. 424 could be divided into a majority of resistant individuals and a few susceptible ones.

Of 273 variants tested for smut resistance 28 were susceptible. S.E.S. 341 was highly susceptible.

Only the uredial stage of *Puccinia kuehnii* occurs on *S. spontaneum* at Coimbatore. A description of this stage is given. The rust affected a large number (127) of the variants in the cooler months and was absent in the hotter months. Its occurrence seems to depend on the prevailing temperature. The disease affected mostly the narrow and medium leaved variants ; the broad leaved ones were in general not affected, particularly those from Assam and Indonesia.

Mosaic was found on 16 variants in the collection.

ACKNOWLEDGMENTS

We are grateful to Mr. N. L. Dutt, Director of this Institute for his sympathetic interest and encouragement, to Mr. R. R. Panje, Botanist, Spontaneum Expedition Scheme for making available the collection of *S. spontaneum* for study and for furnishing data regarding origin etc., of the variants and to Dr. B. L. Chona for helpful criticism and for supplying the culture of *Glomerella tucumanensis*.

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Mr. K. V. Srinivasan then presented the following paper.

Paper

A NOTE ON THE SUGARY DISEASE OF SUGAR CANE

K. V. Srinivasan and V. V. Chenulu
Sugar Cane Breeding Institute, Coimbatore

Thomas *et al* (1945) have recorded the occurrence of *Claviceps* spp. on a number of grasses in South India. Ocfemia (1931) reported the occurrence of ergot on the sugarcane varieties C.A.C. 87 and P.B. 236 in the Philippine Islands and suggested that it was probably *Claviceps purpurea* (Fr.) Tul. Thirumalachar (1943) reported the occurrence of yellowish black sclerotia of ergot on sugarcane arrows in Mysore. The conidial stage has not been described by these authors.

During the month of November, 1954 arrows of K. 567* (one of the clones of *Saccharum spontaneum* hybrids in the ' nobilization ' series (Co. 349 x S. spontaneum S.E.S. 45) at the Sugarcane Breeding Institute, Coimbatore, were affected with sugary disease. From most of the spikelets a sweet, strawcoloured fluid was found oozing out, emitting a strong odour characteristic of ergot infections. Examination of the ' honey dew ' revealed the presence of numerous conidia of a *Sphacelia*. The conidia were hyaline, ovate, occasionally with two guttules, 7.7 x 3.6 (5.6—10.0 x 2.6-4.3) μ. No sclerotia were observed and in the absence of these and their germination producing perithecial capitula it is difficult to identify the species of *Claviceps* involved. *Claviceps purpurea* is confined to the temperate climates and not known to produce infections at the temperatures prevailing at Coimbatore. The organism is further being studied.

The disease is of interest to the sugarcane breeder in that it destroys the majority of ovaries in infected arrows.

We are grateful to Shri N. L. Dutt, Director of this Institute, for his kind interest.

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*Since the submission of the above communications, the disease was observed by us to affect arrows of Co. 419 at Coimbatore in December, 1955.

In the absence of the author the following paper was presented by Mr. K. V. Srinivasan.

Paper

A NOTE ON *SCLEROSPORA* SP. ON *SACCHARUM SPONTANEUM* L.

V. V. Chenulu

Sugarcane Breeding Institute, Coimbatore

Downy mildew caused by *Sclerospora Sacchari* was first recorded on sugarcane by Miyake (1911) in Formosa and later by Lyon (1911, 1915) in Fiji and Queensland, and by Lee and Medalla (1921) and Weston (1920) in the Philippines. In India the only report of its occurrence is by Subrahmanyam (1930) who recorded only the sporangial stage on one occasion. Another species *Sclerospora miscanthi* has been reported by Miyake (1911) on *Miscanthus japonicus.*

Weston (1920) has recorded the occurrence of *sclerospora spontanea* on *S. spontaneum* in the Philippines and this appears to be the only record of the disease on this plant species. He has described the fungus particularly the sporangial stage and differentiated it from *S. sacchari* and *S. philippinensis* (on maize). Though he mentions that the oogonial stage is common throughout the Philippines on *S. spontaneum*, L. no measurements or descriptions of the oogonium or oospore have been given.

At Coimbatore the disease was first noticed during March 1952 on one of the variants of *S. spontaneum* collected from Uttar Pradesh viz. S.E.S. 278. The disease was in a fairly advanced stage with the characteristic symptom of drying and shredding of the leaves. Examination of the leaves revealed the presence between the vascular elements of thick walled oogonia, reddish brown in colour and irregular in shape. The exospore of the oospore was confluent with the oogonial wall which is characteristic of the genus *Sclerospora*. None of the other more than 200 variants was affected. The disease showed itself again during September 1952 after the host had been replanted. The sporangial stage was not noticed on either occasion. The size of the oogonia and oospores of this fungus are compared with other species of *Sclerospora* recorded on *Saccharum* and allied genera in Table I.

This appears to be the first record of the occurrence of *Sclerospora* on *Saccharum spontaneum* in India. Only the oospore stage was noticed and attempts to germinate the spores did not succeed. Whether this form is the same as the one recorded by Weston (1920) on *S. spontaneum* it is difficult to say as the sporangial stage has not been noticed at Coimbatore, while the measurements of the oogonia or the oospores of the Philippine species are not known to the author. Weston (1920) however mentions that in the Philippines oogonial stages of *Sclerospora* have been encountered on *Saccharum spontaneum*,

TABLE 1

Name of the species	Diam. of the oogonium in μ	Diam. of the oospore in μ
Sclerospora sacchari	55-73 x 49-58	40-50
S. miscanthi	48-72	40-56
S. northi var. *seemani* on *Erianthus maximus*	40-70	35-52
S. noblei on *Andropogan austeralis*	...	23-28.9
S. graminicola on Sorghum vulgare	...	33-34.9
S. butleri on *Eragrostis aspera*	...	17-25
Sclerospora sp. on *Eleusine coracana*	...	35-60
S. macrospora	...	60-65
S. iseilematis on *Iseilema laxum*	43-61 x 40-54	38-50
Sclerospora sp. on *S. spontaneum* S.E.S. 278.	86.97 (64.6-115.6)	61-82 (59.6-85.0)

S. officinarum and *Miscanthus japonicus* and the oogonia on these hosts are practically indistinguishable. Judged by the oospore characters the organism under study does not agree with any known species of *Sclerospora*.

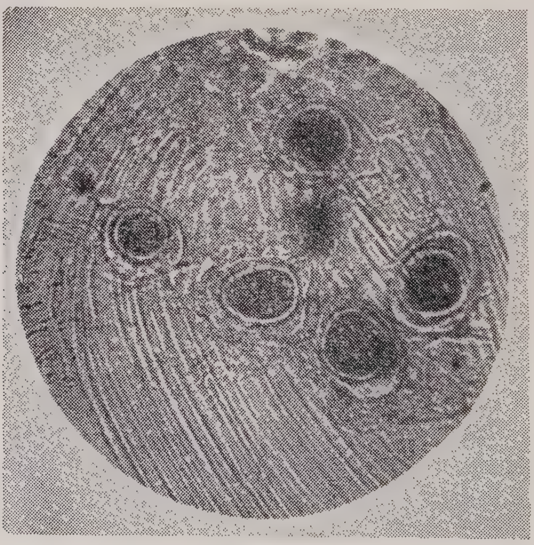

Photo micrograph of Oospores of
Sclerospora sp. on *S. spontaneum*.

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My thanks are due to Shri N. L. Dutt, Director, Sugarcane Breeding Institute, for the keen interest he has evinced in the work and encouragement.

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DISCUSSION

The Chairman observed that they had got a *Sclerospora* on *S. spontaneum* in Delhi, but it was a different species, as in this case only sporangial stage was present and it attacked maize also, thus bridging the gap in our knowledge as to how the Maize Mildew survived in sporangial stage and perpetuated.

In the absence of the authors the following paper was presented by Dr. S. J. P. Chilton.

Paper

STUDIES ON THE SCLEROPHTHORA DISEASE OF SUGARCANE IN LOUISIANA

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INTRODUCTION

An apparently new disease of sugarcane was reported in certain fields along the upper Mississippi River and Bayou Lafourche areas in Louisiana in 1952 by Abbott (1). It was tentatively identified as *Sclerospora* disease and was apparently similar to a disease which had been reported from Australia and Peru.

REVIEW OF LITERATURE

The *Sclerospora* disease of sugarcane was first reported from northern New South Wales in 1940 and was thought to be dwarf disease until microscopically examined (11).

Early in 1952, a specimen of diseased sugarcane from Peru was received by Australian workers for identification. In Peru it had been tentatively identified as dwarf disease, but since dwarf does not occur outside Australia, confirmation was necessary. Examination by Australian workers revealed that it was *Sclerospora* disease (11). Abbott (2) reported that he observed *Sclerospora* disease in Peru.

In June 1952, diseased plants found at the Houma Experiment Station, were diagnosed by Abbott (1) as being affected with a species of *Sclerospora*. This was the first record of positive identification of the disease other than in Australia where it had been under surveillance for approximately fourteen years and in Peru, where it had been recently identified.

The origin of the disease has not been determined, but in Australia, Peru and Louisiana, it is believed to have transferred to sugarcane from some other host, possibly a wild grass (1, 3, 11). A species of *Sclerospora* attacks giant foxtail, *Setaria magna* Griseb., which occurs rather commonly in low, wet areas of the Gulf States, and it is possible that the fungus may have transferred from it to sugarcane. However, proof is lacking (1). In 1952, it was found to attack sorghum, *Sorghum verticilliflorum*, in the Moreton area of New South Wales (11). In 1953, a *Sclerospora* was found affecting Johnson grass, *Sorghum halepense* (L.) Pers. in Louisiana (3).

In the Moreton mill district of New South Wales, in 1947, the *Sclerospora* disease was reported for the first time affecting isolated stools of C. P. 29-116 and P.O.J. 2878 along Petrie Creek (11). In 1952, it became evident that considerable spread had taken place adjacent to the original infested site. It was obvious that diseased cane had not been planted, since the disease did not occur in " stick lots " as would have been expected had the diseased material gone through cutter planters (11).

Abbott (1) stated that the disease did not appear to be widespread in Louisiana, nor was the percentage of infection high in areas of occurrence. However, at the time information to definitely appraise its potential importance was lacking. In 1953, Steib et al., (9) reported the occurrence of this disease on several plantations along the Mississippi River and Bayou Lafourche areas.

Abbott (1) indicated the possibility that this disease might not be new on sugarcane in Louisiana. Records at the Houma Station contain references to abnormally stunted stools of cane referred to as " cluster stool ". The notes on certain of these stools indicated the possibility of a *Sclerospora* infection.

Tims (13) in 1938, reported the occurrence, in 1928, of a dwarf disease in plantings of P. O. J. 234 in Louisiana. The dwarfed stools were made up of large numbers of small shoots emanating from one point through multiple bud production. This disease was maintained in plantings for ten successive years.

Plants affected by the *Sclerospora* disease are characterized by extreme stunting and abnormal suckering so that affected stools consist of shoots resembling a tuft of grass (1, 11). According to Steindl and Smith (10) the yellowish-green colour assumed by the leaves is due to irregular yellowish streaks between the veins. These linear streaks are from one-fourth inch to several inches in length, fairly straight, but not sharply defined. The ends of the streaks are frequently irregular and irregular patches of normal green tissue occur within the streaks. An entire leaf may show these symptoms or they may occur only in discrete areas. Some varieties show the markings more clearly than others (2). These markings may become reddish-brown on older leaves (11). The leaves of affected plants are thickened, abnormally erect (1), or their margins may become wavy in outline, resembling a corn leaf (1, 11). Leaf margins later wither, small sections break off, and the plant has a ragged appearance (1, 11).

According to Steindl and Smith (11) numerous small white specks can usually be seen along the veins which are the resting spores of the fungus. No sign of any mildew or down has been observed in Australia. However, Jones (6) reported that the presence of whitish " clumps " of sporangia on the lower leaf surfaces of orchard grass, *Dactylis glomerata* L., was a characteristic symptom.

According to Abbott and Schexnayder (2) the asexual stage has been observed infrequently in Louisiana. Steib et al. (9) obtained sporangia in greenhouse studies where high humidity was maintained and Farrar and Steib (4, 5) observed their germination by the production of zoospores.

According to Abbott (1) and Abbott and Schexnayder (2) diseased stools often produce unjointed stalks which frequently produce galls of varying sizes and shapes. Buds and shoots may arise from these galls. Occasionally symptomless shoots arise in infected stools (1, 11) and studies indicate that these are free of infection (1). Farrar and Steib (5) and Abbott (1) report that the disease is vegetatively transmitted. However, not all eyes from affected stalks produce diseased progeny (5).

Abbott (1) reports that root development in affected stools is greatly reduced.

Steindl and Smith (11) and Abbott (1) reasoned by analogy that under very wet conditions, the oospores germinate to form free swimming zoospores which are capable of causing infection. Steindl and Smith (11) observed that all localities where the disease was found had been subjected to flood water. Farrar and Steib (5) and Abbott (1) also reported that the disease occurs primarily on low, wet, poorly drained, often flooded, heavy clay soils.

The occurrence pattern of the disease in Australia (11) and Louisiana (5) substantiates the belief that the spores of the fungus are dependent on water for their dissemination. In 1953, Farrar and Steib (5) reported that following the early wet periods in the spring of 1953 an increase from 28 to 54 diseased stools was noted in a three acre plot under observation.

Steindl and Smith (11) reported P. O. J. 2878 C. P. 29-116, Q. 28, Q. 42, Q. 47, Q. 50, Pindar and Trojan as being susceptible. Abbott (1) reported C.P. 44-101 as being susceptible in Louisiana. Personal communication with

Schexnayder revealed that a few diseased stools of C.P. 28-11 and C.P.36-105 were observed.

Steindl and Smith (11) believe that control should not be difficult, since spread is restricted to flooded areas. Abbott (1) stated that diseased stools should be rogued to avoid returning resting spores to the soil. In areas where the disease occurs, planting material should not be taken from land which has been flooded (1, 11).

Abbott (1) found that hot water treatment at 52°C. and 54°C for 20 minutes did not control the disease.

Sclerospora macrospora was described by Saccardo (8) in 1890, from the oospore stage of a downy mildew on *Alopecurus* sp. collected in Australia by Teller. This fungus has been shown to have a wide host range.

Certain workers, while investigating *Sclerospora* diseases, have found evidence to indicate the possibility that another, but closely related organism, may be the infective entity.

Baker, in a discussion following Steindl's paper (10), compared the fungus under consideration with *Sclerospora* and stated that it appeared to be quite distinct from *Sclerospora*. Abbott, in the same discussion, stated that sporangia obtained in Louisiana are considerably larger than those of any species for which this stage has been described.

McDonough (7) from cytological studies of *Sclerospora macrospora* concluded that it would not be placed in any known genus, and that further work might lead to the erection of a new genus.

Thirumalachar, Shaw and Narasimhan (12), after a careful study disclosed supporting evidence for this view and proposed placing the fungus in a separate genus having some characteristics of both *Sclerospora* and *Phytophthora*. While the sexual stage resembles those of *Sclerospora* and some species of *Albugo*, the asexual phase resembles in structure and development, that of *Phytophthora*. They proposed the generic name *Sclerophthora* for this organism which they believed to be a bridging form, intermediate between the *Pythiaceae* and the *Peronosporaceae*. They designated *Sclerophthora macrospora* as the type species for the genus.

EXPERIMENTAL RESULTS

To determine the symptoms associated with this disease, continuing inspections of known areas of infected cane were made over a period of two years.

Under Louisiana conditions, affected stools of the sugarcane variety C.P. 44-101 are characterized by the occurrence of abnormal suckering with stiff, narrow, stunted leaves, which give them a tufted appearance. This condition is shown in Figure 1. Usually there are several apparently normal stalks arising from affected stools. Leaves of young diseased plants are characterised by having irregular yellowish streaks between the veins, from a

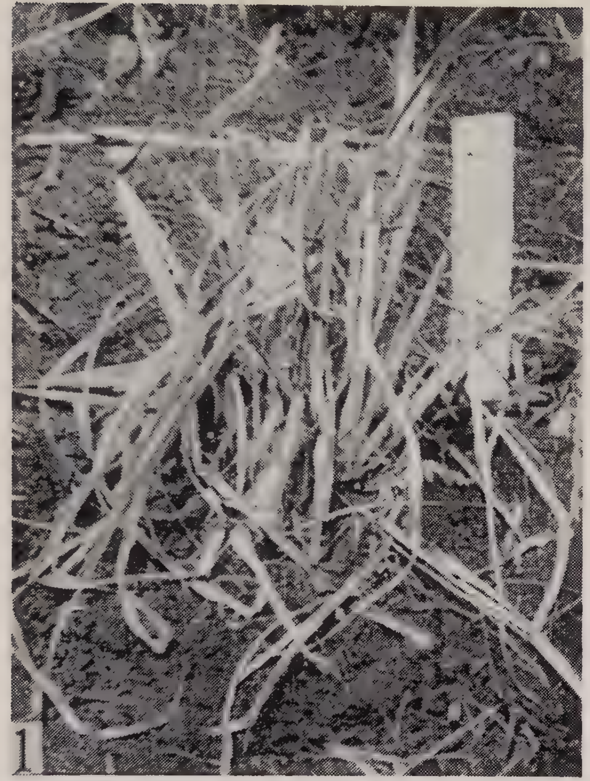

Figure 1. Symptoms of *Sclerophthora macrospora* on C. P. 44-101 at harvest.

few to several centimeters long, with the sides not clearly defined and having irregular ends. An entire leaf or only parts of a leaf may be affected. These streaks later turn reddish-brown with the onset of sporangial production, as shown in Figure 2. A tangled appearance of the leaves is frequently observed. They are thickened, abnormally erect and their margins may become wavy in outline resembling a corn leaf. Frequently small sections from the edges of the leaves break off, causing them to have a ragged appearance. Galls are frequently found on affected plants, these usually giving rise to numerous buds, which, after germination, produce the condition shown in Figure 3.

The root system of affected stools is poorly developed, and as a result, entire stools may be pulled from the ground with little effort. Frequently affected stools fail to " sucker out " in the spring.

OOSPORE STAGE OF THE FUNGUS

To permit microscopic examination of the leaves for oospores, leaves were dechlorophyllized by boiling in 1 N KOH for approximately twenty minutes.

During the hot summer months oospores were found in abundance in the mesophyll tissue surrounding the vascular bundles. The mature oogonia were usually round, reddish-brown, with a wall usually 3-5 microns thick. This is shown in Figure 4. The antheridium was usually singular and persisted on the mature oospores.

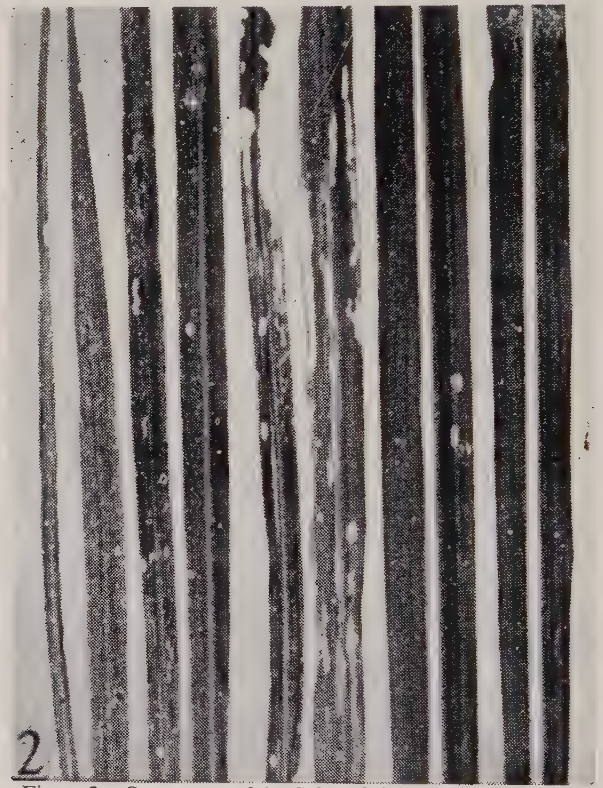

Figure 2. Symptoms of the *Sclerophthora* disease on leaves of sugarcane variety C. P. 44-101.

The matured oospores were thick-walled usually 3-4 microns, and possessed dense granular cell contents with a few oil droplets. The wall of the oospore was confluent with that of the oogonium. Oospores measured 49-72 microns, with an average, based on 1,000 measurements, of 60.55 microns. The mode, however, was from 62-67 microns. Size measurements are given in Table I.

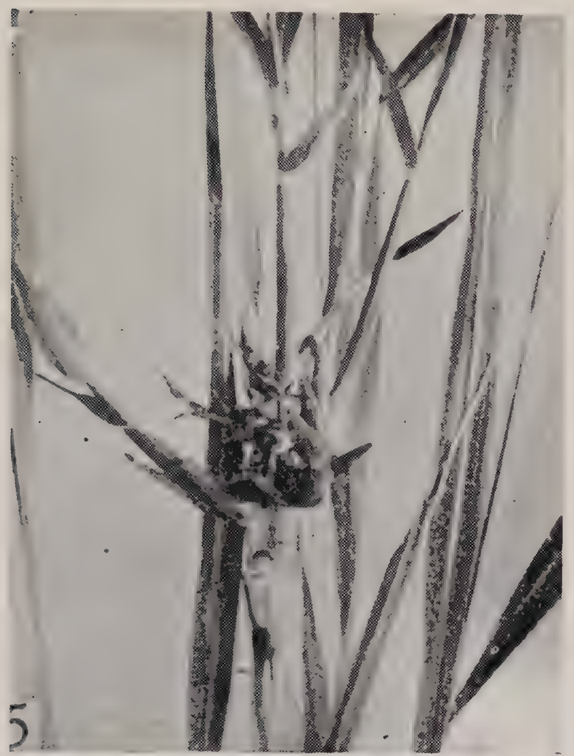

Figure 3. Multiple shoots arising from a gall on C.P. 44-101 affected with *Sclerophthora* disease.

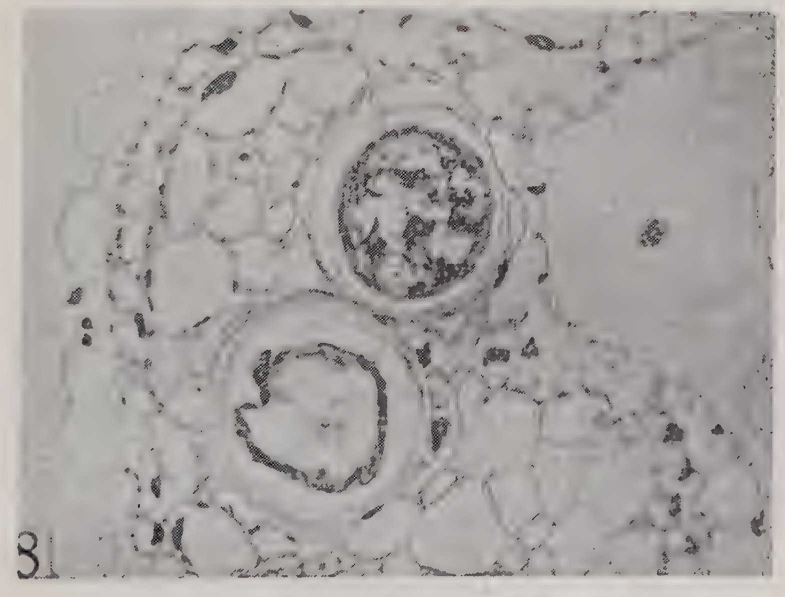

Figure 4. Photomicrograph of cross section of sugarcane leaf, C. P. 44-101, showing oospores of *Sclerophthora macrospora*, X 500.

TABLE I

SIZE CLASSES OF OOSPORES OF *SCLEROPHTHORA MACROSPORA* FROM SUGARCANE LEAVES

Classes (in microns)	Number per 1000
49-51.9	52
52-54.9	108
55-58.9	115
59-61.9	165
62-64.9	263
65-67.9	207
68-72.9	90

Average : 60.55 microns.
Mode : 62-67 microns.

SPORANGIAL STAGE OF THE FUNGUS

Examinations were made for the presence of sporangia both in the greenhouse and the field. Leaf surface scrapings from affected leaves of C. P. 44-101, which were maintained in a moist chamber under conditions approaching 100 percent humidity, were examined microscopically. Subsequent samples were made to determine periodicity of sporangial production. In making samples a drop of water was placed on a scalpel blade prior to scraping the leaf surface.

Histological studies of affected leaf tissue were made using standard procedures and Heidenhain's Iron Alum Hematoxylin stain.

When diseased stools of sugarcane were subjected to periods of high humidity the presence of coenocytic, thin-walled contorted hyphae was observed in leaf surface scrapings. The presence of numerous sporangia, more abundant in the lower than upper leaf surface scrapings, was observed. Regardless of whether plants were placed in the moist chamber in the morning or evening, immature sporangia were produced after approximately three hours exposure, mature sporangia after approximately six hours, and germinating sporangia after approximately ten hours.

The first stage in the development of sporangia was the protrusion of a hyphal branch through a stomate from the contorted hyphae below as shown in Figure 5. This external hypha was 10-15 microns long and functioned directly as a sporangiophore, with sporangia developing at the apex and sympodially. Further observations indicated that sporangial formation was the same as that observed by Thirumalachar et al. (12), with sporangiophores bearing from one to five sporangia sympodially arranged. Mature sporangia were thin-walled, lemonshaped, with apical papillae and were borne on pedicel-like hyphae.

Sporangial production was fairly abundant in the field on spring nights

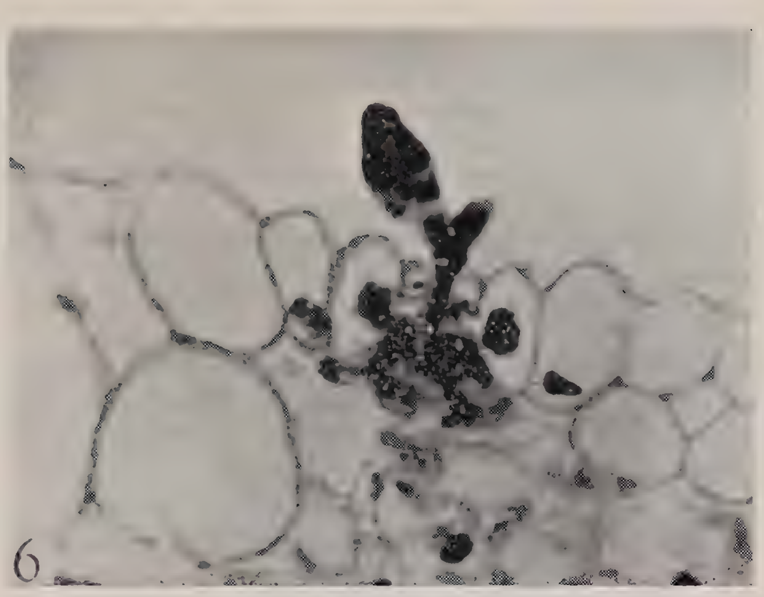

Figure 5. Photomicrograph of a sporangiophore of *Sclerophthora macrospora* showin gsympodial branching, and method of extrusion, X 500.

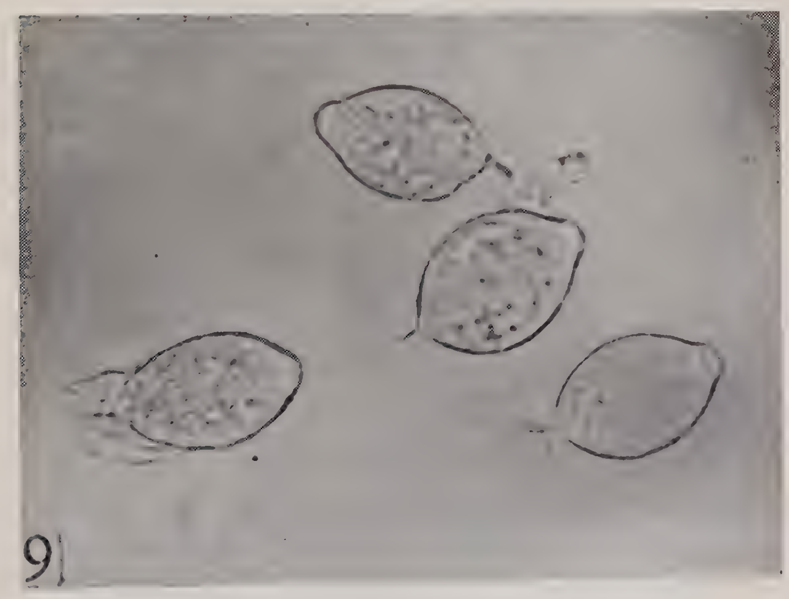

Figure 6. Photomicrograph of sporangia of *Sclerophthora macrospora* from sugarcane, X 500.

when there was a heavy dew or fog. However, no mildew or down on the leaves was observed. Sporangia obtained in this manner are shown in Figure 6.

As the sporangia matured, with the temperature between 60° F. and 80° F., their protoplasmic contents were delimited and reniform zoospores were formed, numbering from 16 to 24 per sporangium, with 24 being most common. After their development the zoospores moved in rotary paths inside the sporangium and within 15 minutes escaped through the apical pore.

In situ germination of sporangia was observed when favourable conditions of moisture and temperature prevailed.

No germination of sporangia was observed on artificial media or in nutrient solutions.

Sporangia were 49-95 microns by 29-65 microns in size, with an average, based on 1,000 measurements, of 74.4 microns by 49.4 microns, however, the mode was from 72-87 microns by 42-54 microns. These sporangial size classes are presented in Table II.

TABLE II

SIZE CLASSES OF SPORANGIA OF *SCLEROPHTHORA MACROSPORA* FROM SUGARCANE

Length		Diameter	
Classes in microns	No./1000	Classes in microns	No./1000
49-51.9	3	29-31.9	3
52-54.9	3	32-35.9	18
55-58.9	5	36-38.9	19
59-61.9	24	39-41.9	62
62-64.9	24	42-44.9	129
65-67.9	83	45-48.9	153
68-71.9	81	49-51.9	177
72-74.9	133	52-54.9	216
75-77.9	121	55-58.9	117
78-81.9	122	59-61.9	47
82-84.9	119	62-64.9	42
85-87.9	135	65-66.0	17
88-93.9	81		
91-93.9	42		
94-95.9	24		

Average : 77.43 x 49.41 microns.
Mode : 72-85 x 42-54 microns.

OCCURRENCE IN LOUISIANA

To determine the general areas affected surveys were conducted, during three growing seasons, in plots of C. P. 29-116, C. P. 34-120, C. P. 36-105, C. P. 43-47, C. P. 44-101 and C. P. 44-155 growing on easily flooded soils.

The *Sclerophthora* disease was found only on C. P. 44-101, in four of five parishes surveyed along the upper Mississippi River and Bayou Lafourche areas in 1952, 1953 and 1954. In June of 1954 it was found on one plantation in the Bayou Teche area.

At no time was the percent of infection found to be more than one-half of one percent.

A microscopic examination was made of leaf tissue from a preserved specimen of multiple bud disease on P.O.J. 234 reported by Tims (13). The presence of oospores in the preserved specimen, indistinguishable from those found in sugarcane, indicated that the causal organism of the multiple bud disease in P.O.J.234 was probably *Sclerophthora macrospora.*

ALTERNATE HOSTS

Grasses growing adjacent to diseased fields of sugarcane were inspected to determine if any were infected, thereby furnishing a possible source of inoculum.

Johnson grass was the only one of the wild grasses which was found to have the disease and the symptoms and signs on it were indistinguishable from those appearing on sugarcane as evidenced by Figures 7, 8 and 9. Tables III and IV show the size classes of oospores and sporangia found on Johnson grass.

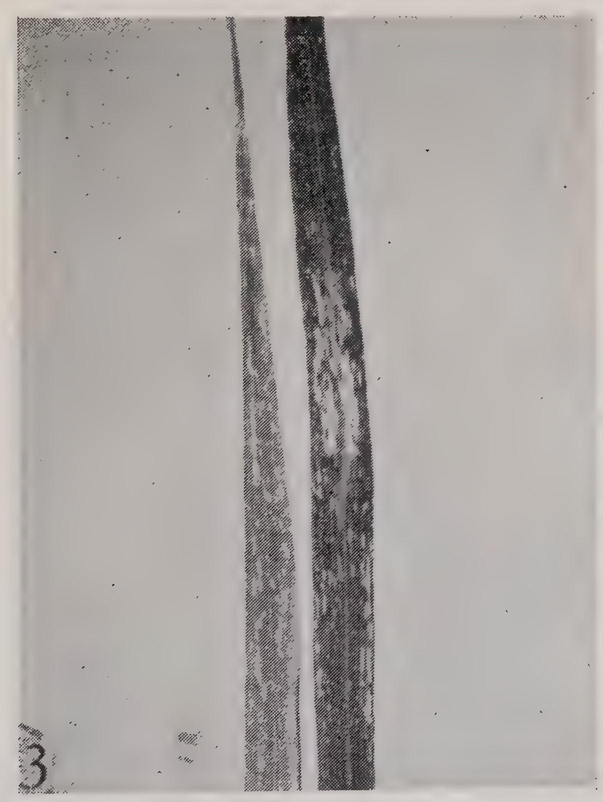

Figure 7. Leaf symptoms of *Sclerophthora* disease on Johnson grass leaves.

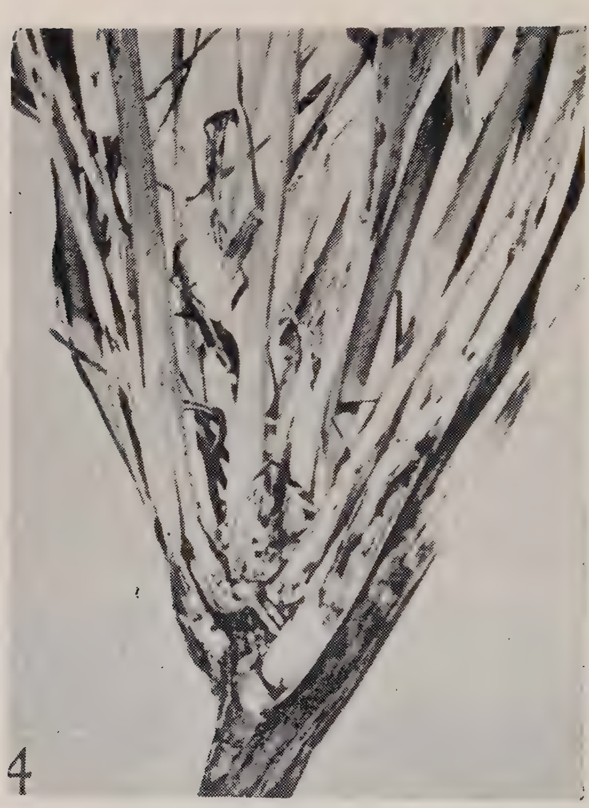

Figure 8. Culm of Johnson grass showing multiple shoots, typical of *Sclerophthora* disease.

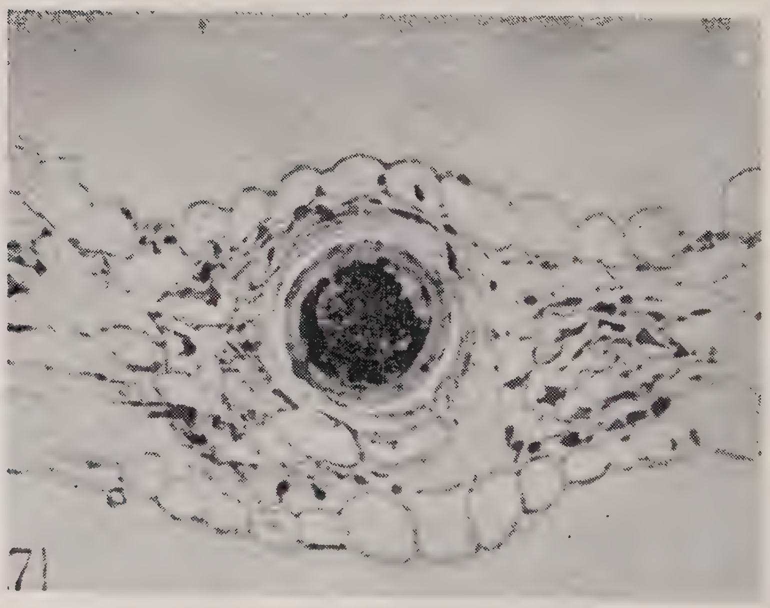

Figure 9. Photomicrograph of a cross section of a Johnson grass leaf showing an oospore of *Sclerophthora macrospora*, X 500.

TABLE II

SIZE CLASSES OF OOSPORES OF *SCLEROPHTHORA MACROSPORA* FROM JOHNSON GRASS LEAVES

Classes in microns	Number/1000
49—51.9	109
53—54.9	231
55—58.9	242
59—61.9	158
62—64.9	163
65—67.9	97

Average : 56.82 microns.
Mode : 52-64 microns.

TABLE IV

SIZE CLASSES OF SPORANGIA OF *SCLEROPHTHORA MACROSPORA* FROM JOHNSON GRASS LEAVES

Length		Diameter	
Classes in microns	No./1000	Classes in microns	No./1000
49—51.9	41	32—35.9	80
52—54.9	52	36—38.9	36
55—58.9	57	39—41.9	291
59—61.9	93	42—44.9	209
62—64.9	108	45—48.9	175
65—67.9	149	49—51.9	154
68—71.9	124	52—54.9	55
72—74.9	118		
75—77.9	102		
78—81.9	66		
82—84.9	38		
85—87.9	29		
88—90.9	11		
91—94.9	12		

Average : 67.53 × 42.78 microns.
Mode : 62-77 × 39-51 microns.

TRANSMISSION

In addition to sugarcane seed piece transmission studies, the effect of flooding on oospore germination and infection, soil transmission, infectivity of air borne sporangia, and infectivity of germinating sporangia placed in spindles, using oospore and sporangial material from both sugarcane and Johnson grass were tried.

Infection was obtained only when sporangia were placed in the spindle of young sugarcane plants. These infections occurred on sugarcane varieties

P. O. J. 2725 and P. O. J. 2878 when germinating sporangia from sugarcane were used and on P. O. J. 2725 when germinating sporangia from Johnson grass was the inoculum. These results are shown in Table V.

TABLE V

RESULTS OF SPINDLE INOCULATION TESTS WITH GERMINATING SPORANGIA FROM SUGARCANE AND JOHNSON GRASS

Test Plant	No. of Plants	No. Infected	Percent Infection
		Sporangia from J. Sugarcane	
P.O.J. 2725	11	2	18
P.O.J. 2878	9	1	11
		Sporangia from Johnson grass	
P.O.J. 2725	10	2	20

Seed piece transmission studies showed that approximately 66 percent of the progeny from seed pieces arising from diseased stools were infected. Table VI details these results.

TABLE VI

RESULTS OF SEED PIECE TRANSMISSION TESTS

		Progeny		
Year Tested[1]	Eyes Planted	No. Healthy	No. Diseased	Percent Diseased
1952-a	50	17	33	34.0
1952-b	25	17	8	32.0
1953	25	3	21	87.5
1954	25	3	18	85.7
Total	125	40	80	66.6

[1] Seed pieces of C. P. 44-101 used throughout.

DISCUSSION

The production of apparently normal stalks of sugarcane by diseased stools was found to be a common occurrence. Greenhouse seed piece transmission studies indicated that these stalks were free of the disease and it is believed that they were shoots that emerged after cessation of sporangial production thus precluding their infection by zoospore penetration in the spindle and leaf sheath areas.

In the hot and arid months of late summer several stunted stools were observed to be in a flaccid condition. The following spring a number of these stools failed to germinate, and therefore, it is believed that, due to poor root development, the hot dry summer and freezing during the winter killed them. This might indicate that the disease tends to be self-limiting in Louisiana.

Since this fungus, in preliminary investigations was found to produce host symptoms and oospores typical of certain *Sclerosporas*, it was therefore, thought to be a *Sclerospora*. However, with the discovery and examination of the asexual stage, it became evident that this stage was not typical of *Sclerospora*, but instead was like a member of the *Pythiaceae*. Further investigations revealed that up to five sympodially branched sporangia per sporangiophore were produced and these germinated by the production of from 16 to 24 reniform zoospores, which were delimited inside the sporangium and escaped through an apical pore. Since these characteristics fulfil the conditions set up for the new genus *Sclerophthora* erected by Thirumalachar, Shaw and Narasimhan, it is believed that this is the same organism.

Disease surveys indicate that the disease, although minor, is widely dispersed throughout the Louisiana sugarcane area.

The examination of the preserved specimen of diseased P. O. J. 234 suggests that the multiple bud reported in 1938 (13) is probably the same disease as the *Sclerophthora* disease.

Successful transfer of the disease from Johnson grass to sugarcane tends to substantiate the belief that the causal organism transferred from a wild grass to sugarcane.

While vast numbers of both oospores and sporangia are produced by infected stools of sugarcane in the field, inoculation with germinating sporangia and field spread studies, indicate the probability that the principal mode of transmission is by water borne zoospores. The occurrence pattern in infected fields in low, easily flooded areas tend to substantiate this hypothesis.

While oospore germination has not been observed this cannot be considered to conclusively eliminate oospores as a possible source of infection.

A high percentage of diseased progeny was obtained when seed pieces from affected stools were planted. This stresses the importance of carefully avoiding the selection of seed material from areas in the field where the disease has been found.

SUMMARY AND CONCLUSIONS

On the basis of host symptoms, oospore characteristics, and sporangial formation and germination, it is believed that the fungus affecting sugarcane and Johnson grass is *Sclerophthora macrospora* (Sacc.) Thirumalachar, Shaw and Narasimhan.

Sclerophthora macrospora was found to be transmitted through the seed piece. Infection was also obtained when germinating sporangia from either sugarcane or Johnson grass were placed in the spindle of healthy sugarcane.

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In the absence of the author the following paper was taken as read.

Paper

THE MAJOR SUGARCANE DISEASES OF NATAL

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The sugar industry, in Natal, is not frequently visited by overseas pathologists and the object of this paper is to give some idea of the sugarcane disease situation over the last 50 years.

The Natal Sugar Industry started in 1850 and from meagre beginnings the industry now supplies the total sugar requirements of the South African market. This highly satisfactory position is the result of good growing conditions and a healthy crop. At present, there is no disease which is a limiting factor to cane growth. It has been said that, "sugarcane in Natal is probably the most disease free crop, grown on an extensive scale, in South Africa". However, many years of research and legislation have been necessary in order to obtain this satisfactory disease position in Natal.

Sugarcane was, until recently, cultivated only in the province of Natal but a few years ago plantations were established in the south eastern part of Transvaal. However, this is only a small area and the bulk of the sugar produced still comes from Natal. The statistics show that there are about 510,000 acres of sugarcane. This sugarcane area is situated mainly along the coast and on an average extends about 10 miles inland ; there are, however, small areas which are farther from the sea.

CLIMATE

The geographical limits of the industry are roughly between 30°E, 31°S and 33°E, 27°S. The average temperature is about 70°F, there being a progressive increase from the southern to the northern extremities. The average monthly variation in temperature is about 14°F, the hottest month being February and the coldest July. Frost in winter is not usual but there are small low lying areas which are frequently frosted. The temperatures are higher than could be expected from the geographical position, due to the warm Mozambique current which washes the shores of Natal.

RAINFALL

In Natal, rainfall is the limiting factor in sugar production—the average rainfall is 40 inches per annum with a variation from 28 to 53 inches per annum. The majority of the rain falls in the period November to March and frequently the winter months (May to July) are extremely dry. Within reasonable limits this dry period is advantageous in increasing the sucrose in cane which is going to be harvested. If, however, the dry spell is prolonged, a large number of canes frequently die and poor ratooning ensues.

From the foregoing it is readily seen that, although sugarcane is grown very successfully in Natal, the climate is nevertheless not ideally suited to sugarcane cultivation. The crop generally is 18-24 months old before being harvested ; there are, however, certain areas of flat alluvial soil where a high temperature is coupled with abundant water and under these conditions the cane is harvested annually and yields of over 70 tons per acre are usually obtained. Unfortunately these areas are small.

STREAK

This disease was apparently first noticed in Natal in 1914 and it appears to have been confused with mosaic until 1922 when Dr. Storey studied the disease and found it to be a virus disease distinct from mosaic. It was then given the name of streak.

This discovery in 1922 was the first record of streak as being a distinct disease of sugarcane and the present distribution of streak is confined to India and the African continent including the islands immediately surrounding it.

Uba, the only variety grown in Natal, at the time was heavily infected. Since this variety has now been almost entirely replaced by other more resistant and higher yielding varieties the disease is hardly ever found except in isolated patches of Uba and occasionally in resistance trials. The disease is completely under control but it has not disappeared from the industry. Experiments recently conducted show that the spread of the disease is much slower than it was previously, indicating that the source of infection has been considerably reduced.

Streak has mainly been a disease of Uba and it is fortunate that the majority of varieties are immune to this disease, as the loss in yield, in Uba, was in the region of 12-15 percent. Streak is no longer of any consequence and for practical purposes can be considered a disease of the past.

MOSAIC

Mosaic can be considered to be the first sugarcane disease, extensively studied in Natal. According to Storey it was probably introduced in 1914 from Argentina in a consignment of Java seedling varieties. This introduction of mosaic had dire consequences for the rapidly developing sugar industry as the mosaic spread to the other varieties grown and throughout the industry.

It was estimated in 1924 that 99.8 percent of the cane area was planted to the mosaic immune variety, Uba. Storey thought that by destroying the mosaic susceptible canes there was a good chance of ridding the industry of mosaic at a relatively low cost. Consequently legislation was passed in 1925 by the Union Government making Uba the only approved variety to be grown. To this variety others have been added and today there are 16 varieties on the approved list. However, they are not all cultivated today.

At the time Storey made the attempt to rid the sugar industry of mosaic he realised that grasses, both annual and perennial, were capable of harbouring mosaic and it was this fact which unfortunately led to the failure to eradicate mosaic. The eradication of susceptible varieties however, reduced the source of infection but the potential danger of mosaic was still present.

Mosaic was not found in the commercial plantations between the years 1925 and 1943. During the latter year an outbreak was found in Co. 281 and since then it has been found in a number of varieties in all the cane growing districts. The incidence of the disease is generally low and usually confined to scattered infected stools of cane. However, there are some small areas, where the perennial grasses are heavily infected with mosaic, where the incidence of the disease is extremely high.

The varieties on the approved list are all susceptible with the exception of the higher numbered P. O. J. varieties and Uba. The other susceptible varieties are more or less tolerant of the disease with the exception of N: Co. 310 and

N: Co. 376. Both these varieties exhibit a fairly high degree of resistance but they are certainly not tolerant ; the loss in yield as obtained in resistance trials over a period of four crops in N: Co. 310 is as high as 50 percent. A feature of mosaic in N: Co. 310 is its high rate of recovery especially in the ratoon crop. It has been found that the third ratoon crop has shown 87 percent recovery when originally planted with mosaic.

The method being used for testing new varieties for mosaic resistance is to interplant the sugarcane varieties under test with a variety of maize known as sweetcorn (sweetcorn has been found to be more susceptible to mosaic than the ordinary variety of maize) which are later artificially infected with mosaic. This creates a large source of infection so that every variety under test has an equal chance of becoming infected with mosaic.

The method used for artificial inoculation may be of interest and assistance to others who have to perform similar operations. The juice from infected leaves is used as a source of inoculum and is extracted by passing the leaves through a small roller mill (similar to those mills used for sucrose analysis except that there are two rollers which measure 1½″ long × 1″ diameter) with a jet of air directed on to the leaf as it emerges from the rollers. This jet of air prevents the expressed juice from adhering to the pressed leaf. The juice is then mixed with Seelite, a diatomaceous filter aid, and some of the mixture is then rubbed, using the fingers or a spatula, on to the young leaves of the plant to be inoculated. The method is rapid and good results have been obtained.

The question of artificially inoculating varieties with mosaic to test their resistance appears to be unsatisfactory as it has been found that some varieties are highly resistant to natural infection but very susceptible to artificial infection. It is the former which is of practical use and it would appear that the artificial inoculation destroys some natural resistance of the plant whether it be some anatomical or some juice peculiarity of the variety remains to be found out. The resistance to natural infection is being used in preference to resistance to artificial infection in assessing the mosaic reaction of a new variety.

CHLOROTIC STREAK

This disease was first identified in Natal in 1952 and disease inspections have shown that it is present mainly in N: Co. 310 and can be found throughout the sugar industry. It has been found in both wet and dry areas but in the former the incidence appears to be higher. The resistance trials have shown that under dry conditions chlorotic streak does not adversely affect the yield but under damp conditions there was a definite decrease in yield. In these experiments it was noticed that the chlorotic streak infected plots produced an excessively large number of "bull" shoots and in some plots as much as 55 percent of the crop came from them. During the growth of the crop an excessively large number of tillers were produced in the chlorotic streak plots resulting in a high shoot mortality due to competition.

The shoots which were left, were weak and so allowed all the bull shoots produced an opportunity of growing without being smothered.

An interesting point is, how did the disease start in Natal ? Strict quarantine regulations have been enforced since 1926 and it is impossible for the disease, if it showed the leaf symptoms, to have got through the quarantine station. It is well known that the symptoms of the disease are produced very erratically but even then it seems unlikely that it could have escaped notice since the canes are kept at least 12-18 months in quarantine and some sort of symptom would have shown up in that period. Hence the mode of entry is purely speculative.

Since sugarcane in Natal is generally grown under dry land conditions it is not anticipated that this disease will cause any undue concern.

RATOON STUNTING DISEASE

This disease was brought into prominence during the International Sugar Conference in Queensland in 1950, which stimulated interest into the possible relationship of ratoon stunting disease with that of yield deterioration or the " running out " of varieties.

The disease is present throughout the Natal sugar industry and the varieties which have been under commercial cultivation longest, appear to be most heavily infected as indicated by the symptoms of nodal discolouration. It is difficult to estimate the loss this disease is causing to the industry, but experiments have shown that a considerable loss in yield in N: Co. 310, can be expected when the fields of that variety have had time to become more heavily infected than they are at present.

An experiment recently harvested showed that, in the variety N: Co. 334, the yield was increased by 76 percent when comparing the yields obtained by planting healthy (hot water treated 50°C. for 2 hours) and diseased cane. The healthy canes were thicker and longer but not more numerous than the diseased cane. The variety N: Co. 334 is not grown commercially, as in an area where it was growing on very poor soil there was an extremely uneven stand of cane. Inspections showed that it was apparently heavily infected with ratoon stunting disease, which diagnosis was later confirmed by experiments.

In Fig. 2 the seed cane was selected from a field which was very variable in height. The tall stools were *assumed* to be healthy (H. Nil) and the short ones were infected with ratoon stunting disease (D. Nil). Both types of seed cane were given the hot water treatment (H. HW) and (D. HW). The photograph clearly shows that if a field is infected with ratoon stunting disease no stools can be assumed to be healthy. The labels indicate the treatment given to the plant cane, the weight and total length of cane harvested.

At the present time not much heat treatment of seed cane for curing ratoon stunting disease is being done. There are two mills which are operating heat treatment tanks, and a few planters have tried making their own treating tanks. The Experiment Station has established large plots of heat treated cane which

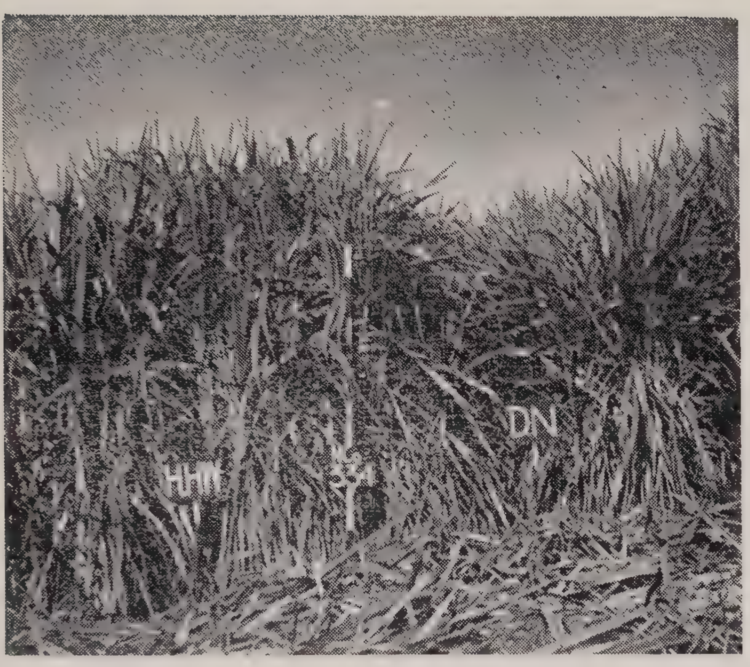

Fig. 1. Shows the effect of ratoon stunting disease on the variety N: Co. 334. The lines on either side of the label DN. are infected with ratoon stunting while those on either side of H. HW are healthy.

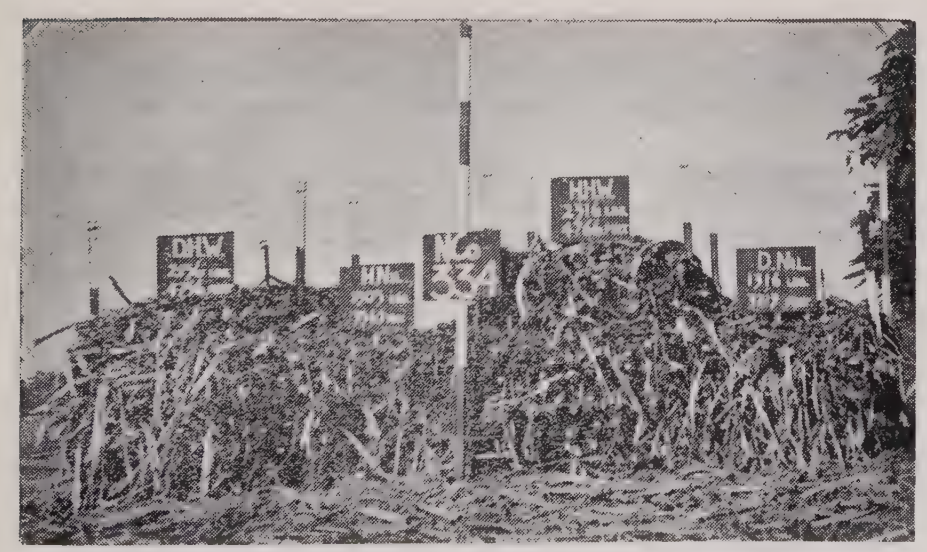

Fig. 2. Shows the effect of ratoon stunting disease on the yield of N: Co. 334.

is available to any planter who would like to obtain disease free seed cane. There is no law in Natal which makes it compulsory for the planters to take steps to eradicate a disease. The elimination of ratoon stunting disease is purely voluntary and it is left to the individual planter to decide what control measures he will adopt.

SMUT : *USTILAGO SCITAMINEA*

Smut was the first disease of sugarcane recorded in Natal. In a publication of a report by the Committee of the Victoria Planters' Association dated 1882 it was stated that " Smut was observed first about the year 1877 and in the succeeding few years made great ravages in the variety of sugarcane known as China cane, eventually almost completely destroying it in this (Inanda) Division." Specimens were sent to the Mycological Institute at Kew and the organism was identified as being *Ustilago sacchari* later the name was changed to *U. scitaminea.* Their report states that " From Natal came the first specimens on the Sugarcane, as far as I (Mr. Cooke) know or can ascertain that ever appeared in Europe." Smut had previously been identified in the Punjab occurring on *Saccharum spontaneum.*

It appears that in 1882 China cane was wiped out with the disease, but apparently with the destruction of infected stools in other varieties the disease was brought under control and disappeared, as no further mention is made of the disease in subsequent literature. However, in 1945 after an absence of over 60 years a few stools of smut were found in Co. 301. Inspite of steps being taken to rogue out diseased stools the disease has spread and Co. 301 is rapidly going out of cultivation mainly because of the high incidence of smut. The majority of varieties on the approved list are susceptible to smut but not to the same extent as in Co. 301.

Smut appears to attack the thin, more hardy varieties, e.g. Uba, Co. 301, Co. 331, Co. 281 and N: Co. 310, and also those which have a high percentage of *Saccharum barberi* in their genetical constitution. Since the harder type of sugarcane varieties are found to be most suitable to Natal conditions it is being found difficult to breed immune varieties. Some good yielding highly resistant varieties have been produced and should help considerably to reduce the incidence of smut.

RED ROT : *PHYSALOSPORA TUCUMANENSIS* (WENT) SPEG.

This disease is comparatively new to Natal. The true red rot disease (*Physalospora tucumanensis*) was first identified in Natal in 1941, although planters had previously spoken of red rot it was mainly *Cephalosporium sacchari* to which they alluded.

The outbreak in 1941 was confined, mainly to two varieties, namely Co. 290 and P. O. J. 2725 and also to the higher altitude areas where there is usually mist and heavy dew. It was in these areas where the greatest damage was done, and several farms had to be nearly completely replanted. Control was soon brought about by replacing susceptible varieties by resistant ones which fortunately were available from the list of approved varieties.

Since the crop in Natal is mainly an 18-24 months old one, the disease is one of the standing cane and not of the planted setts as is the case in many other countries. Field resistance trials have shown that a large number of varieties are resistant and no great difficulty is experienced in producing suitably resistant varieties.

MINOR DISEASES

The Natal sugar plantations have the usual leaf spotting minor diseases which are present in nearly all sugar industries. *Rust* (*Puccinia Kuehnii*) is sometimes very severe and after the uredospores have been dispersed the whole field has a blackish appearance due to the death of the cells between the lesions. Since the very young leaves are often infected and the area of green leaf is considerably reduced this apparently minor disease could conceivably cause some loss in yield. However, the loss must be very small as badly infected fields soon recover when good growing conditions return and at harvest the crop appears to be normal. Pineapple disease (*Ceratostomella paradoxa*) has in the past caused numerous germination failures but this has been overcome with the pretreatment of the seed cane with Aretan or Agallol (mercurial fungicides). This practice is not standard but where the germination is slow the pretreatment is the rule rather than the exception. *Sclerospora* disease (*Sclerospora* sp.) has recently been indentified and a number of varieties have been found infected. It has been found in areas which are periodically flooded and is more of academic interest than of any significance to the sugar planter. An interesting feature of the disease, here, is the very pronounced fanlike appearance of mature infected sticks. It is apparently more usual to have only tufts of shoots rather than large mature sticks infected. The tufts of shoots appear at the base of the stool. Sheath rot (*Cytospora sacchari*) is fairly prevalent and the infected sticks appear thin and distinctly yellow in colour. N: Co. 310 and N : Co. 339 appear to be the most susceptible varieties but pot experiments have shown no decrease in germination due to the disease.

It is interesting to note that no mention has been made of bacterial diseases. In point of fact the only bacterial disease is red stripe (*Xanthomonas rubrilineans*) and this is only found during the cooler months of the year and soon disappears with the warmer weather. The non-occurrence generally of bacterial diseases can possibly be explained by the dry conditions under which cane is grown. There are two big alluvial flats where bacterial diseases could be expected but they have not yet been found.

Mosaic, smut and, more recently, ratoon stunting diseases are at present the main diseases which are causing a certain amount of concern. The loss due to mosaic and smut must be very small. However, ratoon stunting disease is at present rather an unknown quantity and experiments point to their being a severe loss in N : Co. 310 when the variety has had time to become completely infected. The "running out" of varieties is a familiar feature of our industry and if, as has been suggested, ratoon stunting disease is one of the major causes of varietal deterioration then the loss in yield in the past must have been considerable and the loss in the future will be governed by the prophylactic measures adopted now.

SUMMARY

A brief description of the climatic conditions in Natal are given.

The major sugarcane diseases, streak, mosaic, chlorotic streak, ratoon stunting disease, smut and red rot are discussed.

The loss in yield due to these diseases is very small, with the possible exception of ratoon stunting disease where there are indications that a loss in yield can be expected.

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Mr. S. L. Sharma then presented the following paper.

Paper

MORPHOLOGICAL MODIFICATIONS IN SUGARCANE PLANT BY SYSTEMIC INFECTION OF SMUT (*USTILAGO SCITAMINEA* SYD.)

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INTRODUCTION

The modifications in the morphology and anatomy of the host are specially marked when the infection is systemic because the pathogen is in intimate contact of lasting nature. As a result, the long continued presence of the parasite not only depletes the host of its nutrients, but it also introduces end-products of its metabolic activities into the body of the host which manifests its intolerance by developing hyperplasy or hypoplasy. When it is tolerant the physiological activities of both the host and parasite are so well balanced, e.g., *Ustilago tritici* and wheat, that there is no outward indication of the presence of the pathogen till the flowering of the host when it ruptures the host tissues to disseminate its spores. In sugarcane, *Ustilago scitaminea* is not so well tolerated and therefore produces profound changes in the host most of which have been described for the first time in this paper.

MORPHOLOGICAL MODIFICATIONS DUE TO SMUTS

Pathogens grouped under *Ustilaginaceae* to which sugarcane smut belongs do not induce the formation of organoid galls to any great extent. The main target of their attack is inflorescence in which parts of individual flowers may be converted into spore-beds as is the case with anthers of species of *Dianthus* infected with *Ustilago violacea* or with ovary of oats attacked by *U. kolleri*, or *Erianthus munja* by species of *Sphacelotheca* (Khanna and Ramnathan 1946 ; Sharma and Dube 1955) and in several cereal smuts caused by various species of this genus. Very often, florets in their entirety, both male and female, when they are unisexual as in maize attacked by *U. zeae* or bisexual as in wheat infected with *U. tritici*, are destroyed to form sori. In the extreme case of sugarcane smut, the reproductive shoot loses all semblance to an inflorescence and becomes a huge sorus bearing innumerable millions of spores.

Apart from this disruption of flowers, there is little outward indication of the presence of the pathogens of this family except that the ear heads may show minor differences of size, shape or colour. Stem in smut-infected plants of some varieties of wheat and barley may have a purplish tinge, or it may be elongated by *U. hypodytis Elymus arenarius* or reduced in size as is the case in rye when attacked by *Urocystis occulata*. It may be twisted or bent due to the formation of galls by *Ustilago zeae* in maize.

Leaves and roots are much less affected by these pathogens except that the former show slight discolouration in barley on infection with *Ustilago nuda* and develop smut galls in maize. Roots of mustard alone are known to form galls when the plant is attacked by *Urocystis brassicae* (Mundkur, 1949).

In sugarcane, the whip-like spore-bearing structure was suspected to be a converted inflorescence by Butler (1918) long time back. Rafay and Padmanabhan (1940) found a case "in which the terminal portion of a flower-bearing spike terminated into a long much coiled smut whip " and thus furnished proof positive for Butler's hypothesis. Later on Chona (1943) found that in Co. 313, " smutted clumps produced mummified arrows in which lower portion consisted of normal inflorescence with typical flowers while the upper portion of rachis of the inflorescence was converted into a typical smut whip ". He also noted in the same variety some peculiar cases of smut such as hypertrophy of ovary with formation of spores within some flowers and occurrence of smut gall on the internode just below the whip and on young leaves of Co. K. 26, Co. 508 and *Saretha*.

OBSERVATIONS

Observations were made on Co. 313 at Pusa in 1951-52 and 1952-53 while material collected from Co. 453 (ratoon) at Bihta (District Patna) in May, 1951, was used for the study of modifications in flower.

A. *Modifications* : (i) *Stem* :—Sorus-bearing stalks showed reduction in their size the extent of which depended on whether they were formed in ratoon or in plant crop and if in the latter, upon the time of their emergence. In ratoon, thin reedy stalks, 2-2½′ in height and 0.2—0.3″ in diameter consisting of 4-5 internodes with narrow leaves bore smut-whips as early as April i.e., 6-8 weeks after the harvest of the previous crop and continued to do so for the rest of the season except during rainy season. In plant-crop, tillers developing smut early in season either emerged as a smut-whip or were somewhat similar to those formed in ratoon. They, however, got stouter and taller as the formation of sorus was delayed in them.

While the colour of the stalks did not deviate much from the normal, though on a few internodes there were deep green or purplish streaks on lighter green background (Plate 1. Fig. 1a), the shape of the internodes showed much variation depending upon the extent to which the stalk as a whole had suffered reduction in size. In thin reedy stalks, the internodes were conoidal in shape without any of the characteristic features of Co. 313. In others they might be tumescent or cylindroidal without bulge opposite the bud. Their cross-section which normally was perceptibly oval, was strongly so the medium diameter being twice as long as the lateral or was flattened in which case the ratio between the two diameters was reversed (Plate 1. Fig. 1b).

Of the surface markings, bud-groove which in a healthy internode was just indicated over the bud and was hardly palpable in its upper half even at its maximum development, was deep and well defined, extending over the entire length of the internode. In some cases it was deflected from the longitudinal axis of the stalk thus showing that the median plane of the internode had been given a twist (Plate 1. Fig. 1c, d & e). In one case, at the other end of the median diameter, there was another groove with a rudimentary bud. Growth splits and ivory markings, normally absent, were not found in infected stalks also. Nodes which were recessed to some extent in this variety were further sunken so as to be half the thickness of internode at its maximum girth and with the shortening of internodes, a stalk, especially its lower portion, presented a beady appearance.

Of all the structures at a node, bud was the most easily affected. It was completely suppressed on nodes near the terminal sorus and at times upto 6-7 nodes below it. When present, the bud was reduced in size and in extreme cases of modification, became papery thin and elongated like that of *Erianthus munja* (Plate 1. Fig. 1 c). Rooteyes likewise, did not develop on nodes in close vicinity

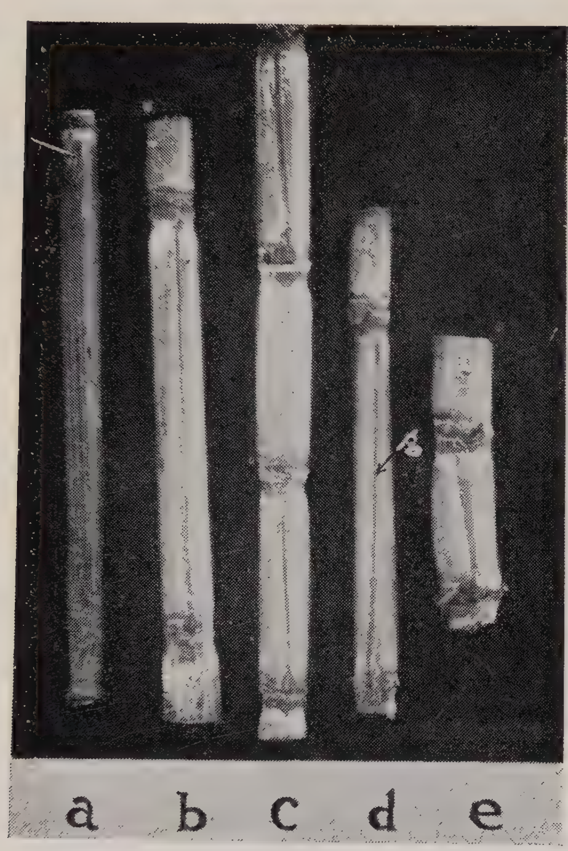

Plate I. Fig. 1. Modifications in stem : g, groove ; l, lamina ; m, midrib ; t, dewlap ; s, sheath ; a, streaks of green or purple on internodes ; b, flattening of cross-section ; c-e, deepening of bud groove and twist in median axis of internode.

of the sorus, while further away, there was only one row of rudimentary rootprimordia present. Leaf scar often became hairy and below it, a circular groove was found particularly in internodes of stalks stunted in growth.

These modifications in individual stalks were accompanied by increase in the number of tillers produced per clump during the season, provided it was not killed in the early stages of development. The potentiality of an infected clump as a source of smut-incoulum could be well imagined considering that a clump was found to have formed as many as 72 tillers most of which terminated in smut sori (Plate 1. Fig. 2).

(ii) *Leaf:* The systemic infection of sugarcane by smut, affected both blade and sheath of a leaf when in close proximity of its sorus. The latter might be reduced in length and breadth as a result of which it often failed to encircle the nodes completely. Or it might become abnormally long as compared with the internode it encased. The blade on the other hand never showed increase in

Plate I Fig. 2. Clump of sugarcane with 72 tillers.
(By kind courtesy of S.A. Rafay)

size. When affected, it was invariably reduced both as regards its length and width or it might become serpentine or be totally suppressed (Plate 1. Fig. 3 c-g ; Plate II. Fig. 1 g-i). The midrib might be affected in the same way or be divided longitudinally into two or three thin wiry strands (Plate 1. Fig. 3 h-k, Plate V. Fig. 3 Arrow 2). Midribs were found to have split in 189 leaves (mostly upper most 1 or 2) in 111 sorus-bearing stalks formed in 64 clumps, the total number of such stalks being 399 in 142 clumps in 1951-52. At times, though rarely, a midrib was absent as a result of which lamina drooped (Plate 1. Fig. 1 a-b ; Plate II. Fig. 2 c ; Plate V. Fig. 3 Arrow 1).

The transverse mark often became oblique and lost its symmetry when the smut-whip was about to emerge (Plate II. Fig. 1 a-c). As a result, the lamina on the two sides of a midrib was not equal in width. Sometimes the obliquity was so much pronounced that the two portions of the dewlap got dissociated from each other and in an extreme case, they were found to be nearly 1½″ apart (Plate II. Fig. 1 f).

In addition to these changes in the leaf as a whole, the compactness of the crown also was altered in some cases when the sporogenous structure was about to emerge. Normally the leaves were fairly well spaced apart with the smut-whip in the centre (Plate II Fig. 2 a). But due to the appearance of supernumerary leaves or shortening of internodes together with increase in the length of sheaths, various degrees of congregation of blades at the top took place. It might be just a slight reduction of space between the transverse marks (Plate II Fig. 2 b) or 6-12 leaves formed within a short distance of 1″ of the stalk might constitute a crown (Plate II. Fig. 2 c, d).

(iii) *Inflorescence* : The presence of the pathogen was found to induce premature formation of arrows though very rarely because during the whole season (1951-52), only four of them were produced in two out of 142 clumps of Co. 313 in an experiment on varietal behaviour to smut planted on 21st February, 1951. The setts for the experiment were artificially inoculated by soaking them in spore-suspension for 24 hours before planting and smut-whips started emerging from 10th May, 1951 onwards. In these two clumps also, they were formed before the appearance of mummified arrows, as would appear from photographs taken on 26th July, 1951 (Plate III. Figs. 1 and 2). In 1952-53 season, none of the 275 affected clumps of Co. 313 nor of any other variety produced such an arrow although the earliest smut-whip was formed on 16th April, 1952.

In both the clumps, arrows which were greatly reduced in size, were borne on thin reedy stalks 50-120 cm., in height and approximately 3-4 mm. in diameter at the most. The culms below them were tomentose with long upwardly directed hairs at the nodes of inflorescence, the racemose branching of which into several rachillae was, more or less, suppressed in the upper portion of the arrow (Plate III. Fig. 3). In the lower portion, the few branches that were formed remained hugging the central axis, instead of radiating gracefully around it. Spikelets showing various degrees of structural modifications in flowers, ranging from slight interference with the development of androecium to irregular branching

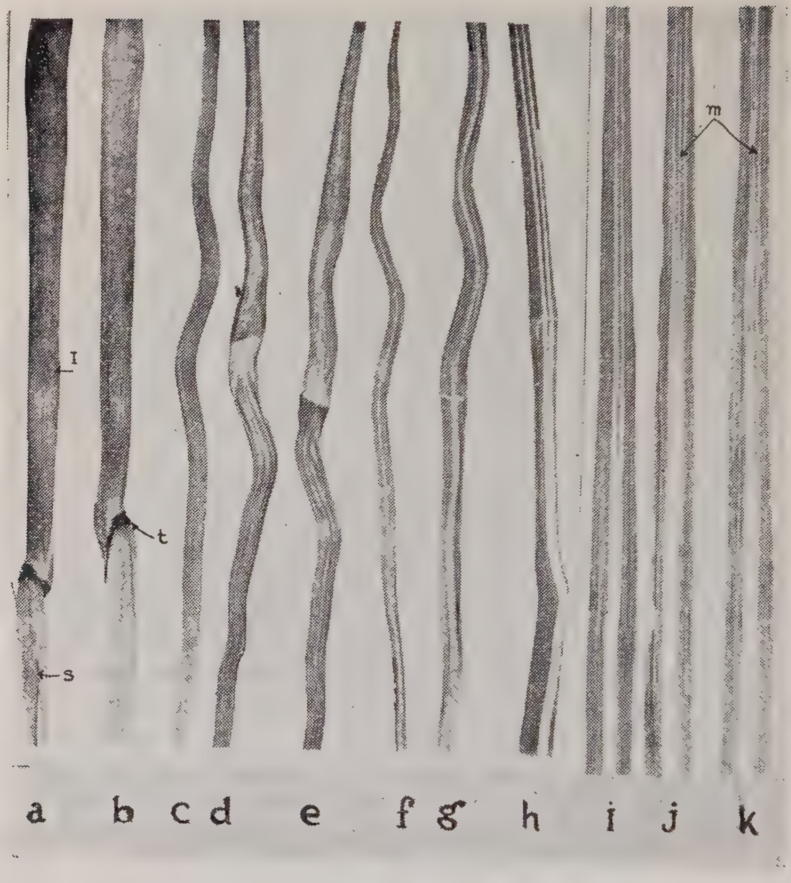

Plate I. Fig. 3. Modifications in leaf; a-e, absence of midrib; c-g, serpentine blade; h-i, bifurcated midrib; j-k, midrib divided into three strands.

of thalamus or its complete transformation into a smut-sorus as much as 5″ long and sometimes accompanied by prolongation of glumes into green foliar structures (Plate III. Fig. 3 d) were formed on these short stumpy branches. In the upper region, however, they were borne directly on the main rachis itself.

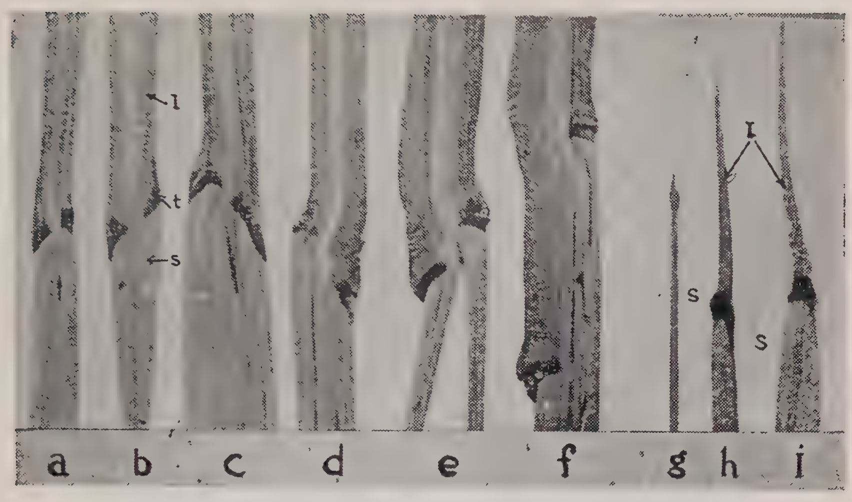

Plate II. Fig. 1. a-c obliquity appearing in dewlap : d-e, dissociation of two halves of dewlap : f, the two halves separated by 1½ ″: g, suppression of lamina : h-i, reduction of lamina.

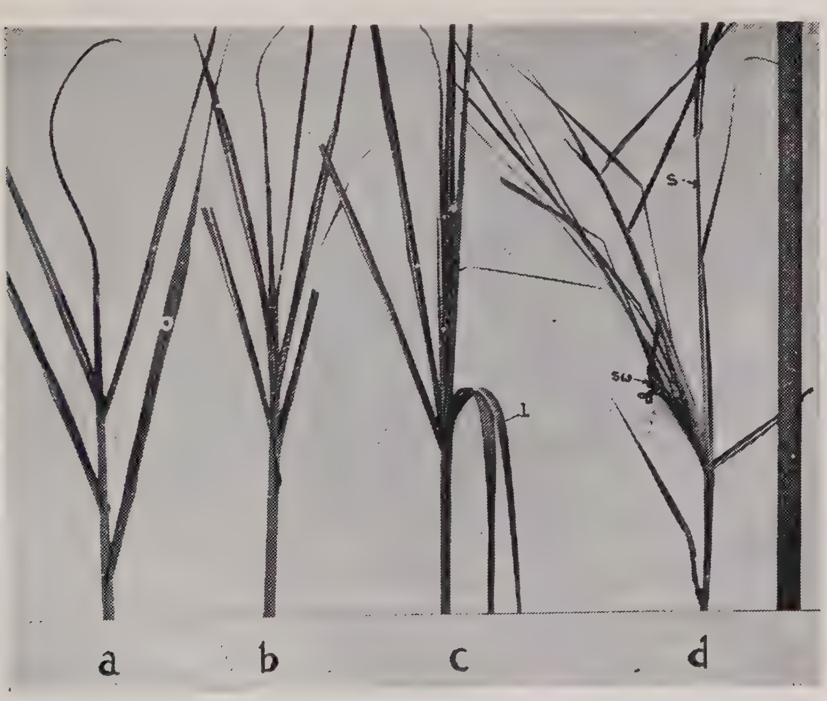

Plate II. Fig. 2. Compactness of crown : a, normal, c and d with 6-12 leaves crowded together.

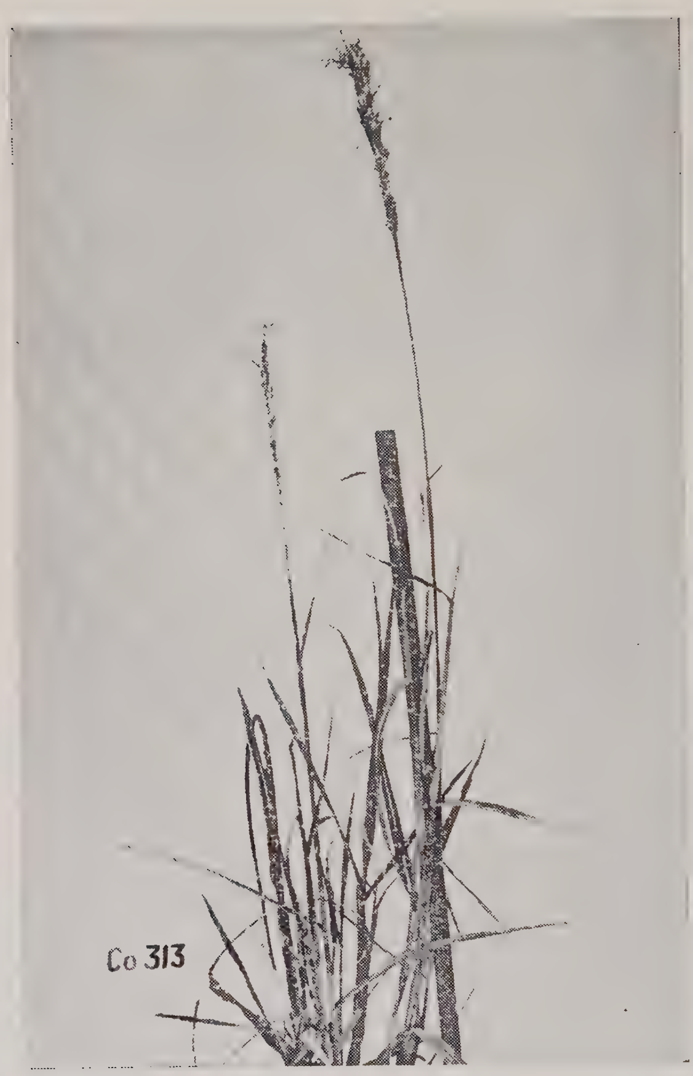

Plate III Figs. 1 & 2 (on next page). Two mummified arrows in each clump with normal smut whips. Photographs taken on 26-7-1951.

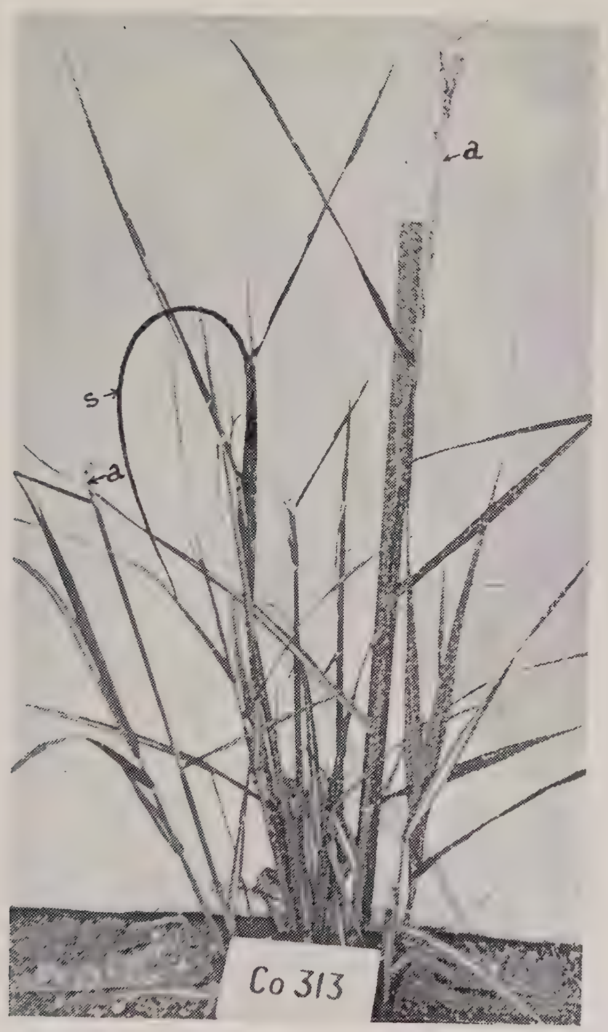

Plate III. Fig. 2.

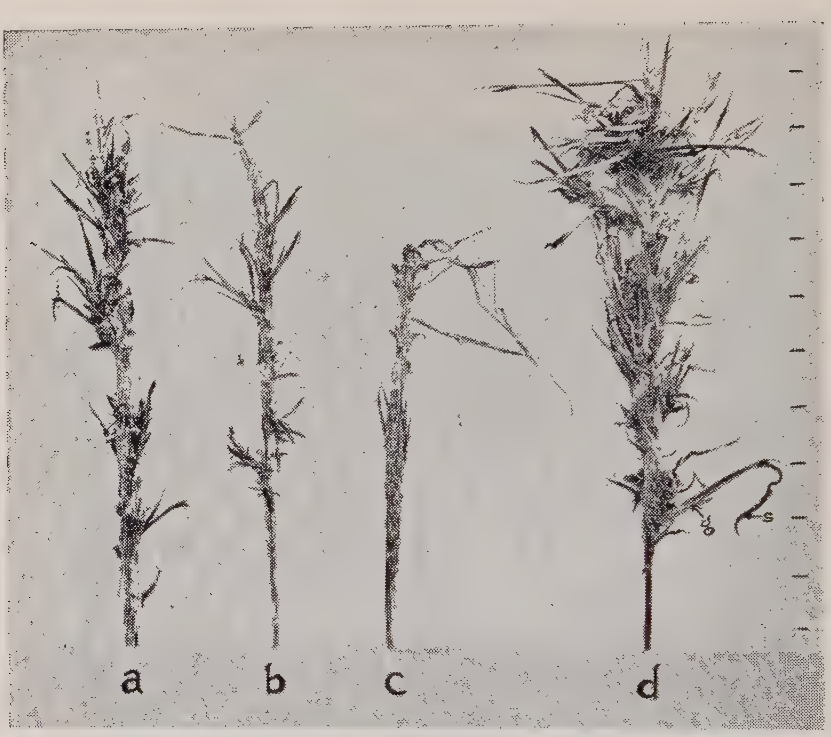

Plate III. Fig. 3. The four arrows mentioned above showing smut whips and enlarged glumes. In d, smut-whip nearly 5″ long and the glume enclosing it about 3½″.

(iv) *Androecium* : Of all the parts of a sugarcane flower, stamens were the most sensitive to the presence of the pathogen the effect of which varied from stoppage of pollen formation to complete suppression of all the three stamens (Table I). The earliest outward indication of disruption in androecium was the reduction in the length of filament which very often became thick also, accompanied by a corresponding change in the insertion of anthers from versatile to adnate type. As a result, anthers did not reach beyond the style, or half the nlegth of stigma and were more or less, rigidly held within the glumes, instead of being exserted and waving freely in air as was the case in a normal flower (Plate IV. Fig. 1).

In anthers which were more often than not shrivelled, lobes might or might not be distinctly visible. Reduction in the size of anthers was always accompanied by formation of short stumpy filaments. When suppressed, stamens, one, two or all the three were completely done away with. Only once in a flower, a staminode was found.

While androecium was undergoing these changes, gynaecium also showed various modifications. But the thalamus and glumes were not much affected

TABLE I

STAGES OF SUPPRESSION OF ANDROECIUM BY SMUT INFECTION IN SUGARCANE

Flower No.	Fig. No. in Plate IV	No. of Stamens	Androecium		Gynaecium			Remarks
			Anthers	Filament	Ovary	Style	Stigma	
1.		3	Shrivelled : tips not reaching beyond half the stigma	Very much shortened	Normal	2 ; Normal	Bifid ; normal	In two other flowers, more or less similar modifications were met with, except that in one case a stamen was converted into a staminode while stamens were completely suppressed in the other
2.		3	More or less normal	Not much reduced in length	Tubular	3 ; Otherwise normal	Trifid, normal	
3.	1	3	Reduced, lobes visible	Very much reduced ; not reaching beyond the stigma	Thick and oblong	6 ; Thick and short	6-fid ; papillae very much reduced	
4.		2	Very much reduced lobes not distinct	short and stumpy	Obconoidal	3; Very small	Trifid columnar; papillae vestigial	One glume reduced in size, the other two normal
5.		2	Very much reduced and shrivelled	Short an dstumpy ; attachedto the II joint	Tubular abutting on the IV joint	1 ; Very much reduced	Three indistinct lobes ; papillae reduced in size	Thalamus elongated with four joints. Glumes 4 on I ; nothing on the III joint ; in another flower similar changes except the elongation of the thalamus were met with
6.		2	Very much reduced : lobes not visible	-do-	-do-	2 ; One from ovary and the other arising from below the ovary at III joint	2 ; One on each style	Thalamus elongated with 4 joints

TABLE I—(Contd.)

Flower No.	Fig. No. in Plate IV	No. of Stamens	Androecium		Gynaecium			Remarks
			Anthers	Filament	Ovary	Style	Stigma	
7.	2	2	Lobes visible at proximal end only	Short and stumpy	Tubular	2 ; One not differentiated from ovary and the other from below the ovary	5 ; 3 on the ovary and 2 on the extra style	
8.	3	1	Thick, lobes not visible	-do-	Oblong	3 ; One very short and thick on ovary ; two from below the ovary	4 ; One fan like on ovary ; 3 on extra styles ; papillae ; short and thick	
9.	4	1	Deeply lobed at proximal end	Reduced in length	2 ; tubular ; one arising below the other	4 ; two on each ovary, more or less normal though of different lengths	4 ; one on each style ; more or less normal	
10.		1	Distinctly lobed but much reduced	Short and stumpy	Absent	1 ; very much reduced	Ellipsoidal ; papillae just indicated	No differentiation between style and stigma
11.	5	1	Very small ; irregularly lobed at distal end	Short and thin	Absent	Absent	Absent	Thalamus elongated and bifurcated into two arms of unequal length and converted into small smutwhips ; glumes 7 ; 3 of normal size and thickness and 4 very thin and papery above them ; short hairs below glumes and also at the node of bifurcation present.

Note :—1. Abnormalities of thalamus and glumes, if any are given in ‘ Remarks ’ column.
2. Callus hairs as a whole were absent or reduced both in length and density in all these flowers as well as those given in Tables II and III.

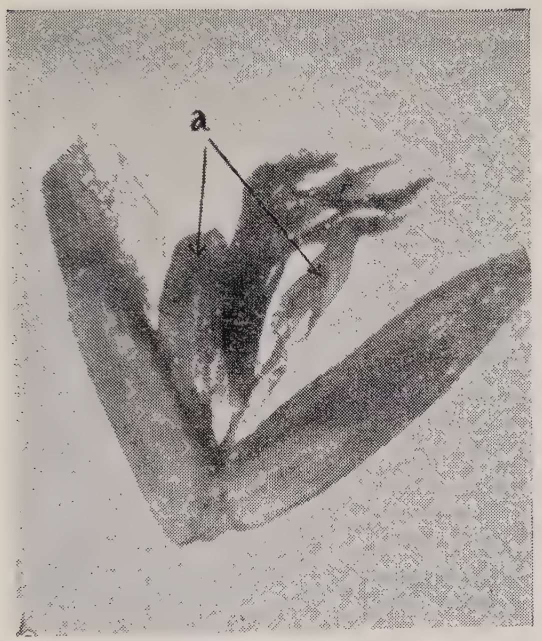

Plate IV. Fig. 1. Anthers on short stumpy filaments : s, stigma six-lobed.

except that the former lengthened out into fournoded axis and in the case of the latter, 1-3 extra papery thin structures were formed. It is interesting to note a case of a flower in which one stamen was found to persist even when, gynaecium having been completely suppressed, the thalamus was converted into a small smut sorus curved upon itself and seven glumes in place of the normal three were developed (Plate IV. Fig. 5). Usually such drastic derangement in a flower was not found associated with the presence of androecium.

In no case, spores of smut were found to have been formed within the anthers or filaments nor was there any change in the insertion of stamens on the thalamus *vis-a-vis* other parts of a floret, namely the glumes and gynaecium.

(v) *Gynaecium* : The reaction of gynaecium differed from that of androecium in that there was not only suppression but proliferation also as against suppression only in the latter (Table II). There might be, in a flower, two ovaries arising one below the other (Plate IV. Fig. 4) or as many as six well developed or several indistinctly defined styles* on an ovary (Plate IV. Fig. 1) or 1—α supernumerary styles attached to thalamus at different levels with 2-4 stigmas on them in some cases (Plate IV. Figs. 2,3,7). Disruption, usually began with

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*As gynaecium in sugarcane consists of a single carpel, two styles and two stigma in a normal flower might be regarded as two arms of a single style and stigma.

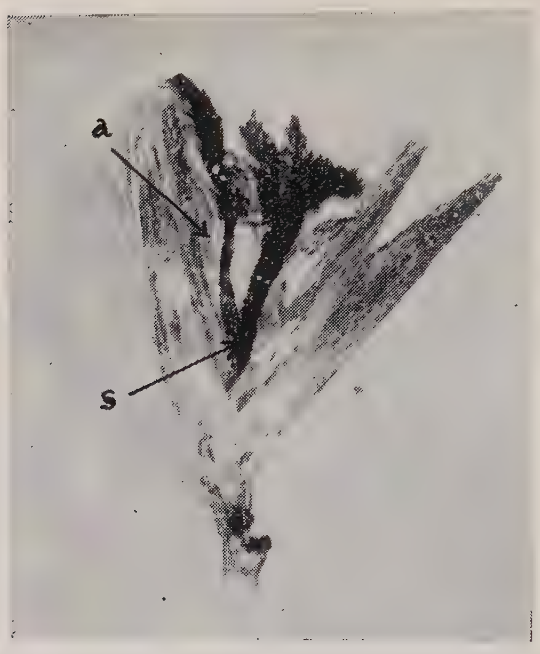

Plate IV. Fig. 2. One style arising below the ovary.

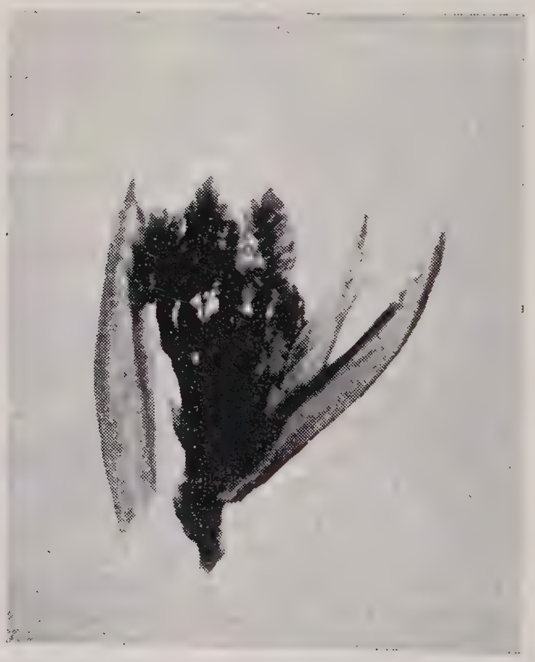

Plate IV. Fig. 3. Several styles of different sizes arising at various levels.

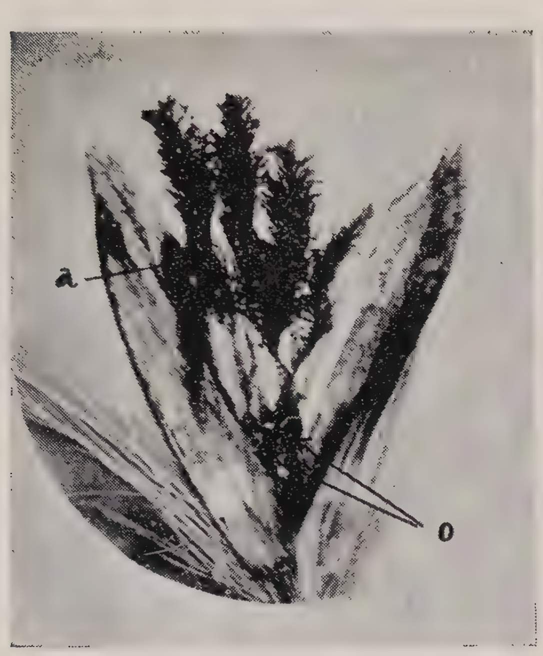

Plate IV. Fig. 4. Two ovaries with two styles each : stigmas normal.

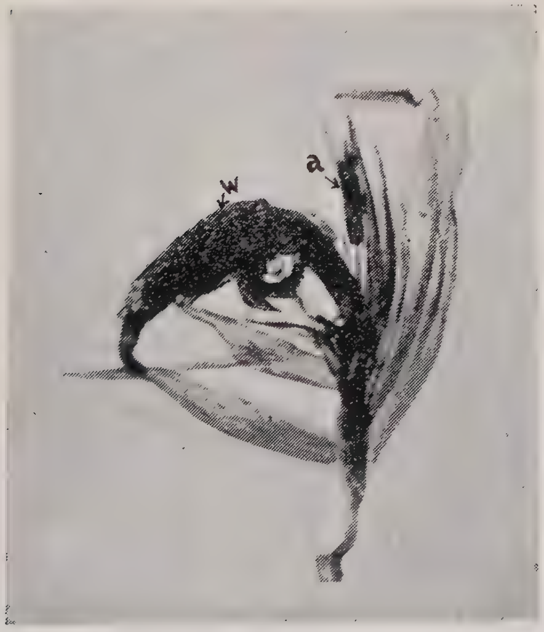

Plate IV. Fig. 5. Smut-whip formed after bifurcation of thalamus ; glumes seven and one anther present.

TABLE II

MODIFICATIONS INDUCED IN GYNAECIUM BY SUGARCANE SMUT

Flower No.	Fig. No. in Plate IV.	Ovary	Styles	Stigma	Thalamus	Remarks
1.		Tubular, tapering downwards	Absent	2 ; abutting directly on the ovary	Elongated with 2 joints	In another flower, stigma was found to be 5-fid, but without elongation of the thalamus.
2.		Tubular on the VI joint	3 ; that on ovary much shortened, the other two arising from IV and V joints	5 ; 2 on ovary style ; 3 on extra styles ; papillae more or less normal	Elongated with 6 joints	Glumes 4, of normal size ; but arising at different nodes.
3.	6	Tubular	Tubular ; smut spores formed on sporophores, outside its walls	Pappillae indicated	Elongated	Very faint differentiation between ovary and style and between style and stigma. Sporophores consisted of a thick hyphal strand with a semicircular or reniform head on which spores were held aloft in air. In another flower with 4 glumes, spores were formed within the ovary itself as well as on sporophores.
4.	7	Absent	2, of different thickness and arising from the thalamus one below the other	6, on the slender style and 4 on the stouter one which branched twice ; papillae reduced in size to some extent	Elongated	In another flower. there were 3 styles with a stigma each, having more or less normal papillae

TABLE II—(Contd.)

Flower No.	Fig. No. in Plate IV.	Ovary	Styles	Stigma	Thalamus	Remarks
5.	8	Absent	Several arising at different levels and of various sizes, progressively shorter from below upwards	Several ; one on each style except on the longest which has two ; normal papillae present in stigma of longer styles	Elongated with 5 joints	Glumes 7 of normal size
6.		Absent	Absent	Degenerated stigma at the top as indicated by papillary nature of the tissues	Branching irregularly with thin papery glumes forming empty urceolate structures with papillary fringes at tips	
7.		Absent	Absent	Papillae faintly indicated	Tubular with black streaks indicating spore beds	In other flowers, similar modifications with the supernumerary glumes reduced in size with or without papillae were met with

Note :—1. In these flowers, androecium was completely suppressed.
2. Abnormalities of glumes, if any are given in " Remarks " column.

ovary and was carried upwards to stigma which was often indicated by papillary tissue even after the ovary and style were completely suppressed. The urceolar shape of the former was the first to go, it becoming tubular and often tapering downwards or massive or obconcidal in shape. The two arms of the style were fused into a single short stumpy structure undifferentiated from the ovary below or stigma above in extreme cases of disorganisation. Stigma no longer remained the efficient pollen-catching mechanism that it was because apart from the reduction in its size, the papillae became short and thick (Plate IV. Figs. 1,3,8). In advanced stages of disruption, they were just indicated by tissues faintly resembling them at the terminii of styles or at the barren tips of thalamus branches (Plate IV Fig. 9).

Spores of smut were found to have been formed inside the gynaecium which was discernible as an entity distinct from thalamus. Spores were also formed on sporophores very much similar to the conidiophores of *Rhizopus stolonifer* or *Eurotium* each consisting of a single hyphal strand* 5.3 μ in diameter with a semicircular or reniform head approximately 84 μ broad and 71 μ high. These protruded out of the ovary walls to approximately 472 μ and held spores aloft, exposed in air for their easy dissemination (Plate IV. Fig. 6). This is the first instance of formation of smut spores on specialized hyphae. Usually they are formed indiscriminately by almost all the hyphae which happen to be exposed to air.

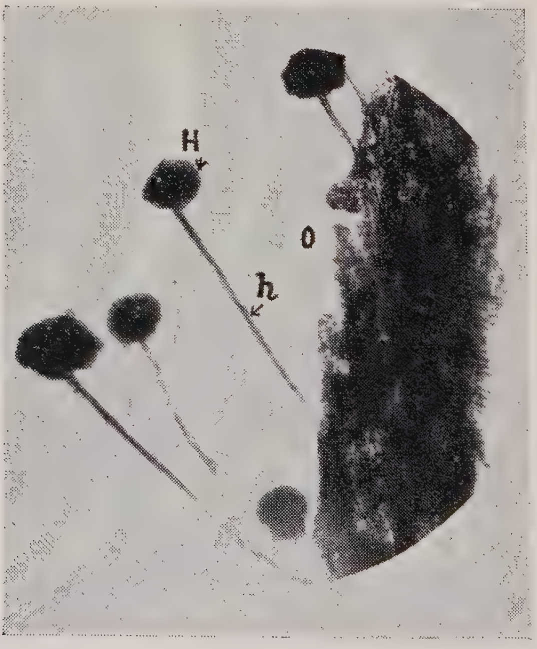

Plate IV. Fig. 6. Spores formed on sporophores held aloft outside the wall of ovary by thick hyphal strands.

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* The thickness of ordinary hyphae bearing spores was found to be approximately 1.5μ.

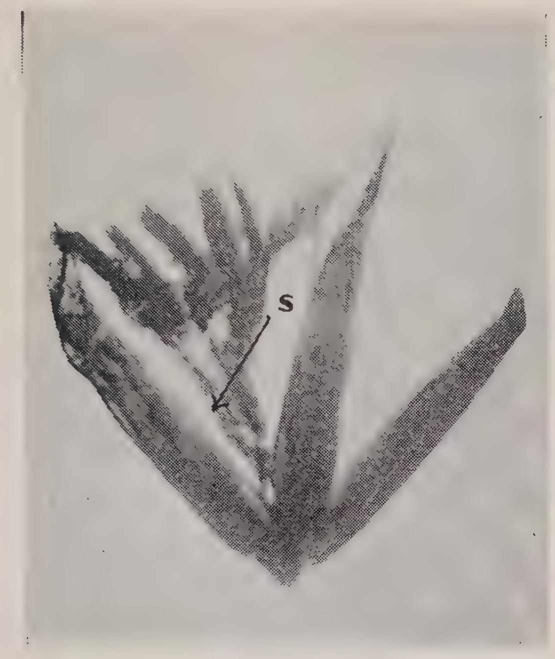

Plate IV. Fig. 7. Style arising from thalamus one below the other.

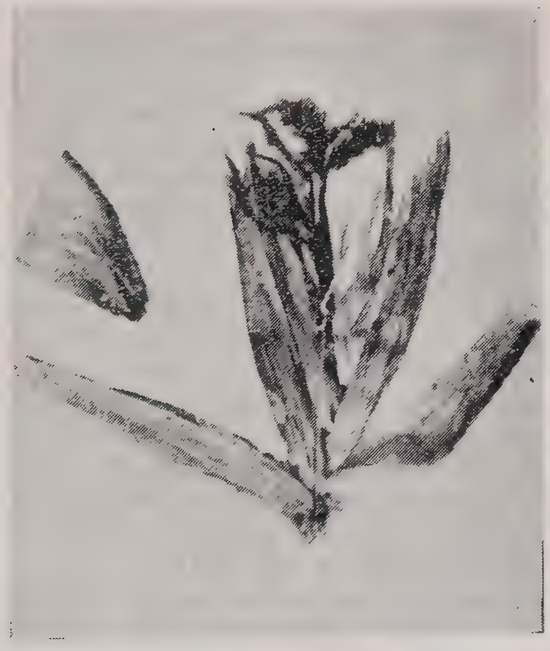

Plate IV. Fig. 8. Several styles arising at different levels and of various sizes, stigma reduced to thin papillary strands in 2 cases.

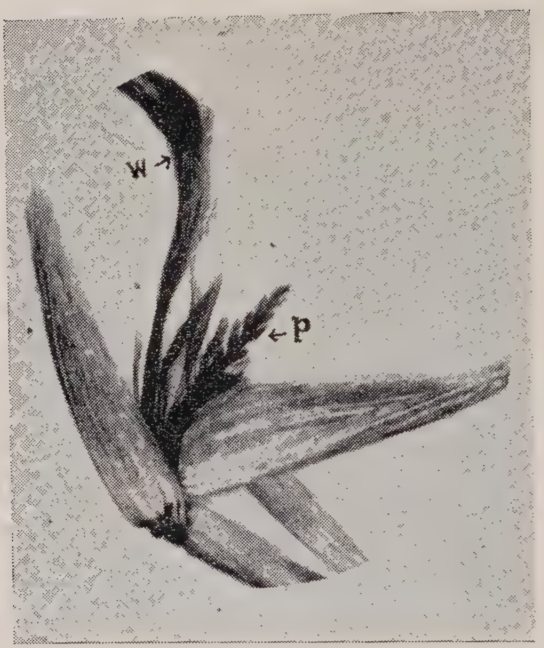

Plate IV. Fig. 9. Thalamus branching into two ; one is with papillary tissues only ; the other very hairy and with a smut-whip (broken) encased in a sheath.

(vi) *Thalamus and Glumes* : Changes in thalamus and glumes usually occurred after the complete disappearance of androecium and gynaecium (Table III). The former might elongate, sometimes with the formation of nodes which might be as many as six in number on which different floral parts were attached, or it might be converted into a small smut sorus either as such or after it had bifurcated into two small arms (Plate IV. Fig. 5). If these arms failed to develop into sori, they subdivided further, sometimes irregularly, sometimes on uniparous scorpioid cymose pattern, into small branches having at their ends, barren urceolate structures formed by two thin papery bracts. Hairs of various lengths appeared at nodes where branching occurred, and sometimes all over them. In one case, each of the two arms formed as a result of bifurcation of the thalamus above the glumes, bore a deformed floret one of which had its own set of 4-5 glumes. Their thalamii subdivided further and had vestigial gynaecium at two of the branches of one arm, while at the tips of those of the other were borne sterile urceolate structures mentioned above (Plate IV. Figs. 10,11,12).

Increase in the size of glumes and the appearance of supernumerary ones took place at a very advanced stage of derangement though the two were not found associated with each other. They would elongate and develop into green foliar structures often differentiated into a sheath and a vestigial blade. Rudimentary

TABLE III

CHANGES BROUGHT ABOUT IN THALAMUS AND GLUMES OF SUGARCANE FLOWERS BY SMUT

Flower No.	Fig. No. in Plate IV.	Thalamus	Glumes	Remarks
1.		Thick massive ; greatly elongated and curved upon itself ; hairy all over	3 ; paperly at different levels	
2.		Converted into a tabular smut sorus $1\frac{1}{2}''$ long	3 ; enlarged ; $\frac{3}{4}''-1''$ long; green ; differentiated into a sheath and rudimentary blade	Curved smut sorus with hairs all over was found in another flower
3.		Elongated and bifurcated above glumes ; spore-beds on one branch curved on itself ; the other broken ; hairy all over	3 ; normal	Between the glumes and smut sorus the thalamus resembled a rachilla
4.	9	Bifurcated ; one branch slender and elongated ; very hairy with a bract like structure enclosing a smut-sorus ; the other arm short and thick with a glume and a few branches ending in blunt lobes		
5.	10	Bifurcated ; both arms branching further irregularly (somewhat on cymose pattern) ; nodes hairy in both ; at tips empty structures formed by two thin papery bracts	6 ; enlarged ; $\frac{1}{2}''-\frac{3}{4}''$ long	

TABLE III—(Contd.)

Flower No.	Fig. No. in Plate IV.	Thalamus	Glumes	Remarks
6.	11	Thalamus bifurcated above the glumes ; each arm bearing a deformed floret at its end.		
		Floret I. Thalamus elongated and like a rachilla ; hairy at nodes ; 5 glumes, rather small and thin ; further branching into 4 strands of which two subdivide again having empty bract-like glumes at the tips ; the remaining two branches resemble vestigial ovaries with very poorly developed styles and stigmatic surfaces		
		Floret II. Above 4 thin glumes, thalamus branched into three ; one branch further divided irregularly ; pubescent ; empty bract-like structures at tips ; the other two with vestigial ovaries and stigmas ; distinct papallae on one ; five rudimentary ones on the other	2 ; enlarged ; ½″-1″ long	
7.	12	Bifurcated just above the attachment of glumes ; both arms showing cymose branching ; uniparous scorpioid ; one arm branching 5 times and the other 9 times ; empty bract-like structures usually 2 present at each end ; in the upper portion of the main branch and in the lowest branch empty bracts absent	3 ; enlarged ; ½″-1″ long	

Note :—In these flowers, reproductive organs were completely done away with.

leaves 2″-3″ in length encasing whip-like sorus 4″-5″ long (formed as a result of conversion of a thalamus) were often met with at the apex of the mummified arrows (Plate III. Fig. 3 d). Smut spores were not found to have been formed in glumes nor these were suppressed in any of the flowers studied.

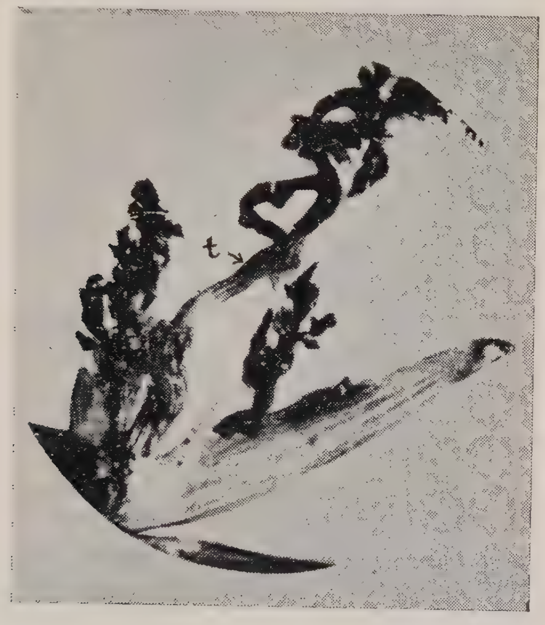

Plate IV. Fig. 10. Bifurcation of thalamus ; arms sub-dividing further ; tips with barren urceolate structures.

Callus hairs were reduced both as regards the density and the length of individual hair or completely done away with. Rachillae and thalamus especially near the nodes where branching took place were, however, found to be pubescent, the hairs being short unless formed at the nodes themselves.

(vii) *Roots*—No observation on roots were made.

B. *Abnormal Galls* : (i) *Two terminal whip-like sori* : During the course of the study, three such cases described below were met with.

(a) The upper most two internodes of the stalk were about 3-5 cm. long and approximately 1 cm. in diameter with distinct smut galls on them (Plate V. Fig. 1). At the apex, two whip-like sori more or less equal in size were formed and were encased within the same leaf-sheath. It appears that soon after the division of the growing point the two resulting arms were converted into sporogenous structures.

(b) In this case (Plate V. Fig. 2) the smut-whips were formed after the growth primordia had produced 2-3 leaves each below them. Smut-cankers as black

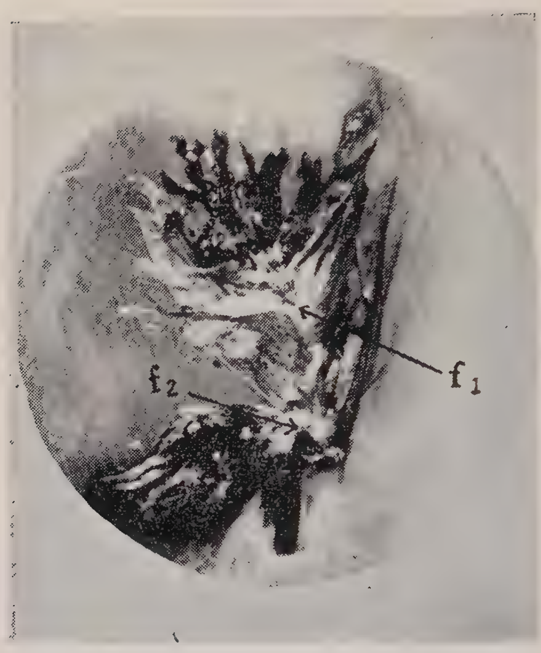

Plate IV. Fig. 11. Bifurcation of thalamus ; two degenerated florets with their own glumes and vestigial floral parts.

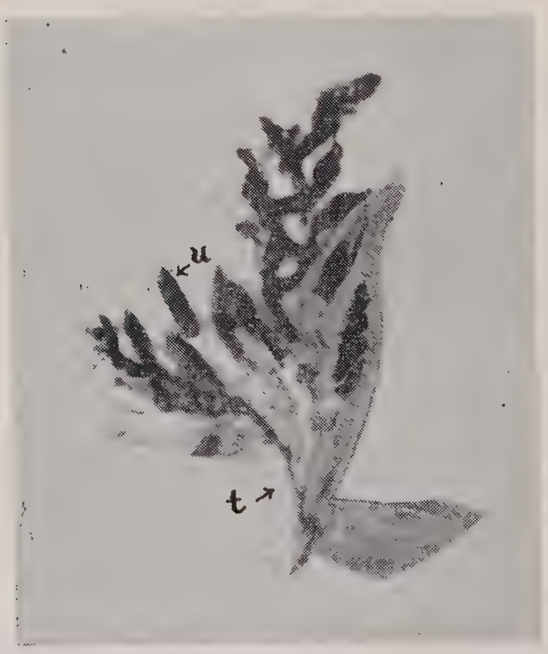

Plate IV. Fig. 12. Bifurcation of thalamus ; two arms sub-dividing further and bearing at their end-branches barren urceolate structures formed by two thin bracts.

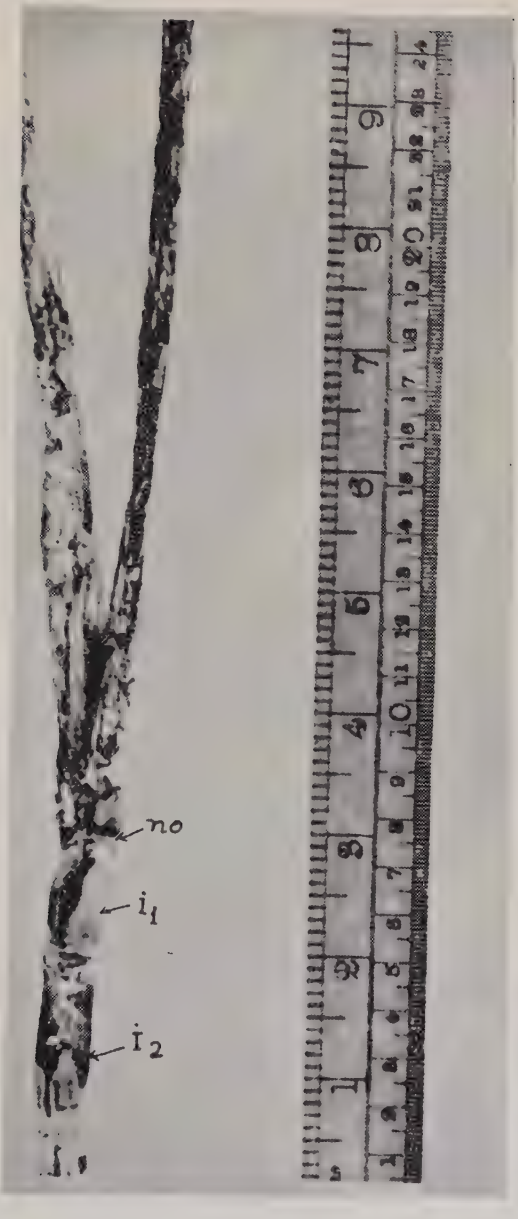

Plate V. Fig. 1. Abrupt fission of apical growth primordium.

streaks were present on the 3rd internode, 4.5 cm. in length below the node of bifurcation and progressively enlarged their area on the last two internodes. Leaf-sheaths enclosing these internodes failed to encircle the nodes completely. Both the sori were encased separately in leaf-sheaths.

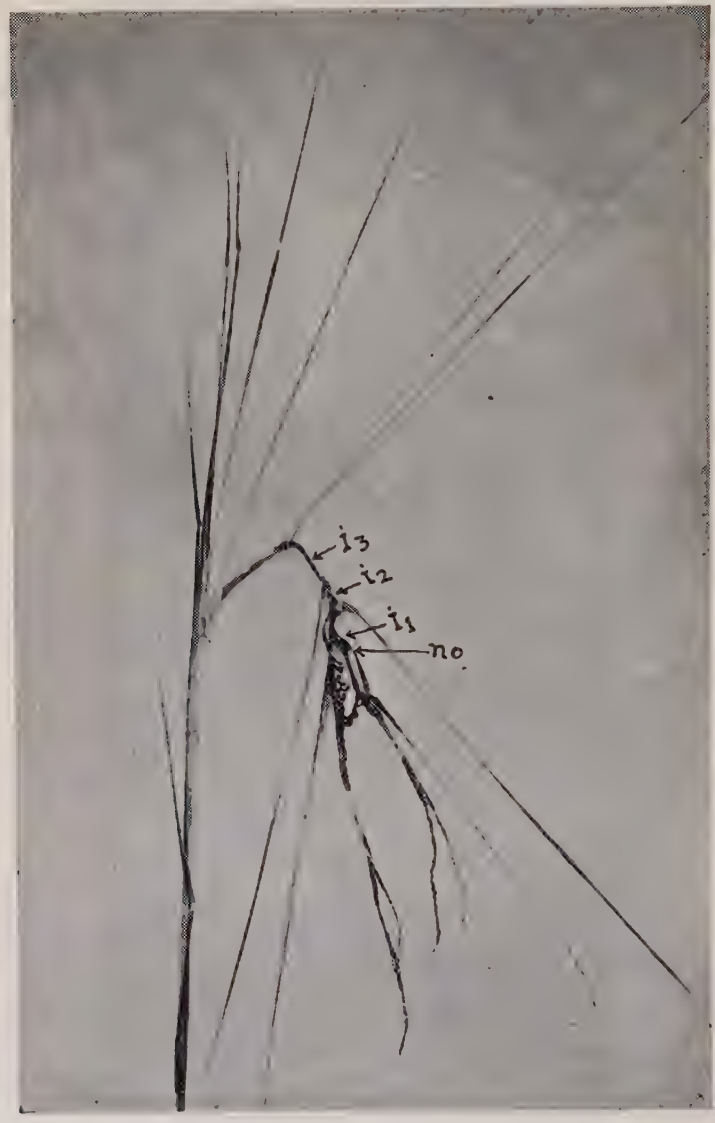

Plate V. Fig. 2. Bifurcation of terminal meristem delayed.

(c) In the third case, the formation of the sporogenous structures lagged very much behind the bifurcation of the growing point. Here an apparently healthy internode 5-6 cm. long with 5-6 leaves more or less in a whorl was produced by each of the two growth primordia before they were converted into smut-sori. On the first node below bifurcation. 12 leaves with sheaths varying from 0.5 cm. to 14.2 cm. in length were formed within a space of 2.5 cm. on the stalk. In one of these leaves, the midrib was absent while in another it had bifurcated (Plate V. Fig. 3) .

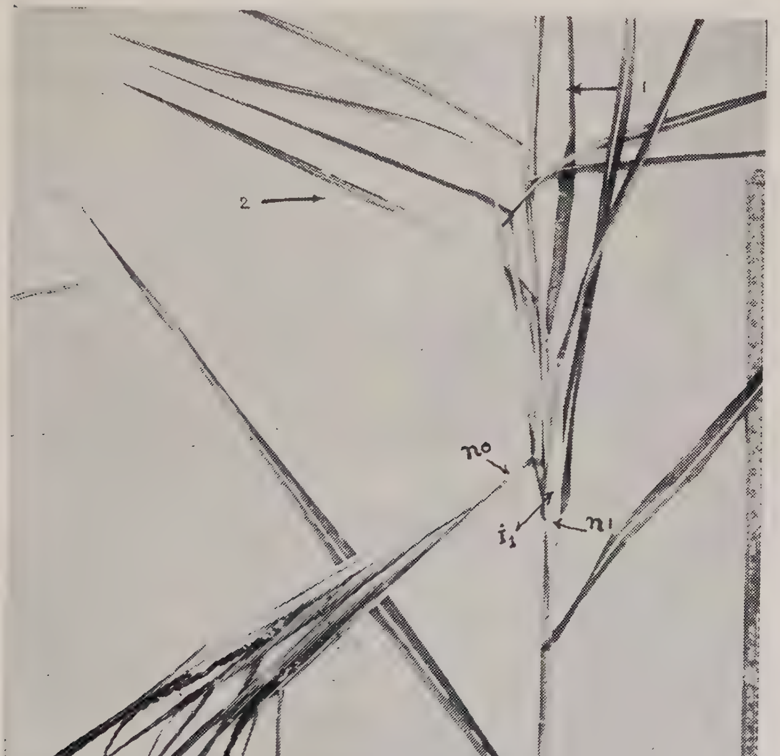

Plate V. Fig. 3. Slowest bifurcation of all the three.
Arrow 1, midribless leaf ; Arrow 2, bifurcated midrib.

(2) *Smut Galls on Midribs* : The blade of the last leaf was often found in intimate organic contact with the smut-whip along its midrib which at times developed spores within it. Lamina was usually free on one side of the midrib, and had no galls on it, that on the other side having been merged with the sporogenous tissue of the stem. Sometimes there would be gaps of 2″-3″ between pieces of lamina found attached to the smut whip (Plate VI. Fig.1a). In one case, spores were found on a midrib which had free lamina on both the sides, and was quite separate from the main whip like smut-sorus (Plate VI. Fig. 1b).

(3) In several cases of smutted stalks, sporogenous as well as apparently healthy tissues, were formed side by side for considerable distance before the stalk developed smut spores on its entire periphery. As such they showed various types of deformities due to distortion and hypertrophy (Plate VI. Fig. 2 a, b).

DISCUSSION

(a) *The excitant* : From the observations given under Section III, it would appear that the over-all effect of the systemic infection of sugarcane plant by smut is the reduction in its size as a whole, though some parts showed a graded series of reaction from stimulation to suppression with intervening stage of proliferation, and reduction as given below :

1. Stimulation of existing growth primordium.
    - (a) Elongation of leaf sheath.
    - (b) Elongation of glumes and their conversion into green foliar structures.
    - (c) Elongation of thalamus.
2. Formation of supernumerary growth primordia.
    - (d) Tillering in a clump.
    - (e) Development of leaves more or less in whorls in close vicinity of a much elongated whip-like smut sorus.
    - (f) Appearance of extra ovary, styles, stigma and glumes in flowers.
    - (g) Branching of thalamus.
    - (h) Formation of hairs at nodes where thalamus branches.
    - (i) Bifurcation of stalk.
    - (j) Longitudinal division of midrib in a leaf into two or three smaller midribs.
3. Reduction resulting in suppression.
    - (k) Stem ; reduction only.
    - (l) Sheath, lamina and midrib in leaf.
    - (m) Inflorescence.
    - (n) Androecium, gynaecium and callus hairs in a flower.

It seems the extent to which an organ would be modified would depend upon the concentration of the potent factor which did not seem to be the physical presence of the parasite in the organ itself because its mycelium in different parts of leaves namely the sheath, lamina, midrib and transverse mark and in

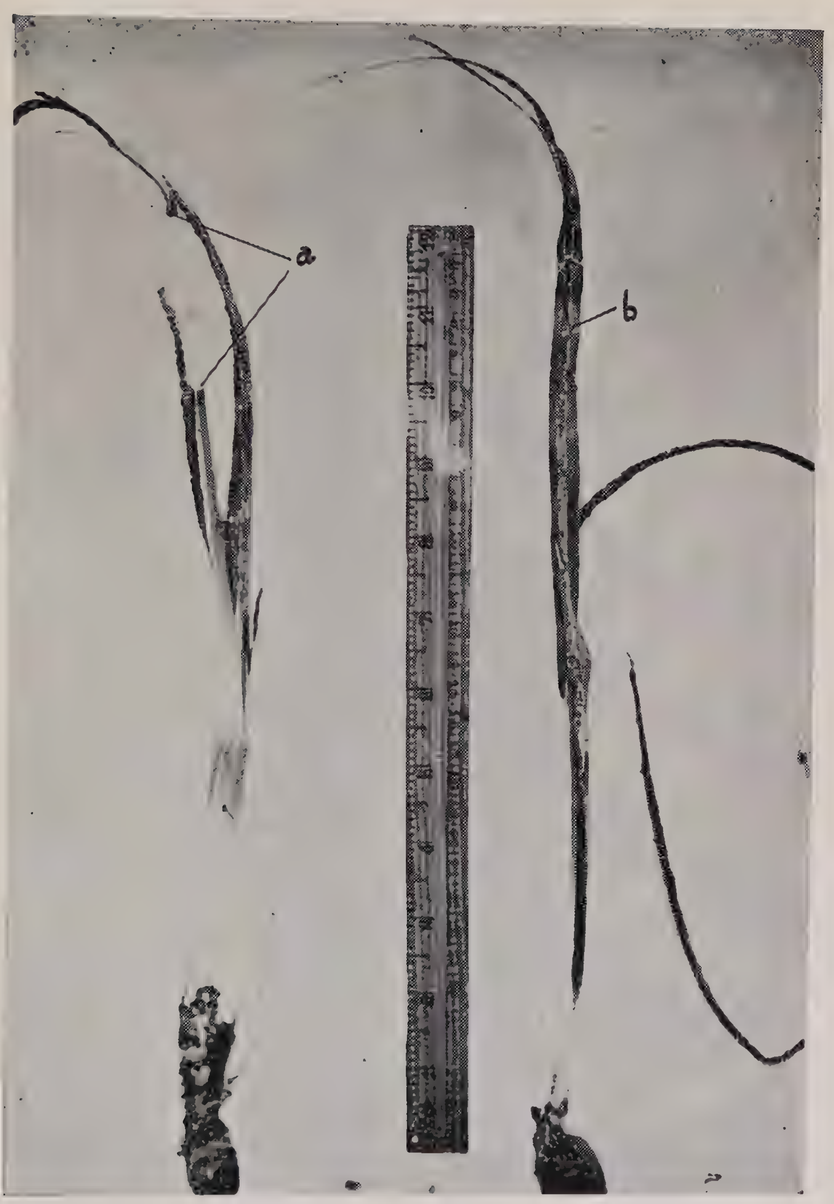

Plate VI. Fig. 1. Midribs converted into sori, a, pieces of lamina attached to normal whip ; b, free midrib with sorus.

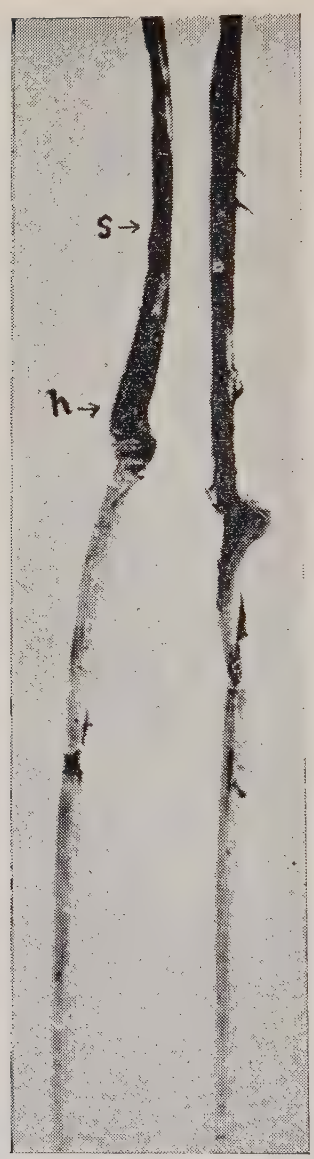

Plate VI. Fig. 2. Two stalks with apparently healthy and sporogenous tissues formed side by side for sufficient length.

andrcocium, gynaecium and glumes in the case of flowers, was not recorded so far by any worker nor by the author. In the abnormal galls also, Chona (1943) found it to be absent from the leaf tissues ½″ beyond the lesions which had therefore, developed from local infection quite independent of the systemic one. Further the formation of smut whips, more or less equal in size and the splitting of midrib into strands of approximately equal thickness in the upper half of the leaf, appeared to suggest that the disturbing element like the one causing fission of stalks into two arms of equal size (Sharma and Khanna, 1949) was very subtle in its action. As such, the modifying element could be none other than the by-products of the metabolic activities of the parasite thrown out into the system of the host and carried in due course to various developing organs because Brain *et al* (1952) showed that alternaric acid, one of the metabolites of some strains of *Alternaria solani*, when introduced into the vascular system of cut shoots of tomato and potato, travelled upwards and caused necrotic lesions of the stem, petioles and leaf-blades, very much similar in appearance to the lesions appearing in some phases of natural attack by *A. solani*. It was able to produce similar lesions on plants out-side the host range of the pathogen.

The concentration of these substances would obviously depend upon the proximity and amount of smut mycelium, in other words the nearer the seat of their manufacture, the higher the concentration and consequently the greater the resultant degeneration in a developing organ as would be evident when the three cases of bifurcation of stem are taken into consideration. In the first case, the formation of large smut galls in 3 internodes below the two terminal smut sori at the bases of which leaf primordia were suppressed, showed that the interval between the bifurcation of the terminal growing point and the entry of mycelium in sufficient quantity to produce smut cankers was not as long as it was in the third case in which due to the proliferation of leaf primordia, the formation of 5-6 leaves each at the bases of smut whip-like sori above the point of bifurcation, (Plate V. Fig. 3 n3) the presence of 12 leaves at the node n_1 below it and the formation of an apparently healthy internode i_1 in between, appeared to suggest much weaker excitation. It progressively became stronger as would appear from the gradual decrease in the length of leaf sheaths formed at n_1 given below acropetally (in cms.).

(1) 14.2 (2) 10.5 (3) 12.5 (4) 11.6 (5) 10.1 (6) 7.0 (7) 5.4 (8) 4.9 (9) 6.9 (10) 2.6 (11) 1.1 (12) 0.5.

The second case occupies an intermediate position because only 2-3 leaves each at the bases of the smut sori as also at the node below that of bifurcation were formed and the smut galls were represented by black streaks on 3 lower internodes (Plate V. Fig. 2). Similarly splitting of midribs was found to occur only in upper most 1-2 of 6-8 leaves formed on a smut-whip bearing stalk.

(b) *Morphological Nature of Smutwhip* : When the comparatively rare occurrence of mummified arrows, the short-photoperiodic nature of sugarcane plant, the potency of summer days to push it back to vegetative phase even when

(b) *Morphological Nature of Smutwhip* : When the comparatively rare occurrence of mummified arrows, the short-photoperiodic nature of sugarcane plant, the potency of summer days to push it back to vegetative phase even when the change over to reproduction is fairly well advanced (Sharma 1953 ; Sharma and Srivastava 1955) and the formation of spores on lamina and midrib of a leaf and on internodes, are together taken into consideration, the probability of smut whip-like sorus being a converted stem is greater than that of its being a modified inflorescence which it has so far been supposed to be. The sole basis of this supposition was the intuition of Butler (1918), analogy with cereal smuts, and a few greatly reduced arrows with their upper portions converted into smut-sorus found by others. The hypothesis formulated here appears to be further supported by the formation of a greatly elongated sporogenous structure in non-flowering varieties and the stage of physiological maturity of plants in general at the time of their formation. Smutwhips can emerge when plants have hardly produced 3-4 small leaves which indicates that the terminal growing point within the bud meant for vegetative growth has been set upon by the smut-mycelium without giving it a chance to develop even a single internode. Sometimes lateral buds which have not been known so far to bear inflorescence in sugarcane are also stimulated to produce miniature whip-like smut sori. That its abrupt change from vegetative to reproductive growing point is highly improbable is also borne out by the fact that premature arrows have not been recorded on mother shoots so far. In these two clumps also. several normal whips were formed before the development of arrows on daughter shoots. As regards the analogy with cereal smuts, it does not hold good especially when one takes into consideration that the formation of their spores is strictly confined to flowers, while that is not so in the case of sugarcane smut. Even the rachis is not involved so far as sporulation is concerned in the former. Different species of the same genus are likely to affect not only different hosts in different ways but also the same host in a variety of manner. For instance in *Erianthus munja*, arrows may be formed in May when attacked by *Sphacelotheca schweinfurthiana* as reported by Khanna and Ramnathan (1946) or they may develop at the normal flowering season i.e. November-January, when the host is attacked by another species namely *S. sacchari*, of the same genus (Sharma and Dube 1955).

SUMMARY

1. (a) The commonest of all the modifications induced by systemic infection of sugarcane plant by *Ustilago scitaminea* was the general reduction in its size the extent of which depended upon the nature of crop and time of production of smut whip.

(b) The internodes often lost their characteristic shape with median plane, sometimes, slightly twisted. The bud groove deepened and extended over the entire length of the internode which might at times show streaks of deeper green or purple in colour.

(c) Bud and root eyes were completely suppressed for as many as 6-7 nodes below the smut-sorus. When present, the former was elongated and papery, while there were only a few of the latter in one row.

2. In leaf, the lamina and sheath showed various degrees of reduction in size ending in suppression. The latter might sometimes be elongated as well and its base might not completely encircle the node. The midribs of the uppermost 1-2 leaves were very often bifurcated and in rare cases completely absent. The transverse mark often became oblique and its two halves got disjointed, though rather rarely. In an extreme case, they were nearly 1½″ apart.

3. (a) Four arrows in two clumps of Co. 313 planted in February emerged prematurely in July. They were borne on thin reedy stalks and were without any rachillae in the upper portion. A few, formed in the lower portion, were very much reduced in size and remained hugging the central axis. In several cases small whip-like sori upto 5″ in length were formed on them, accompanied by elongation and conversion of glumes into green foliar structures which showed rudimentary differentiation into a sheath and a blade.

(b) Androecium were the earliest of all the floral parts to be affected. Filaments were shortened and thickened while anthers were reduced in size and undifferentiated into lobes. One, two or all the three stamens may be absent. No supernumerary stamens were found nor smut in them.

(c) Concurrent with these changes in androecium, gynaecium was also modified showing all the stages from proliferation to suppression. Supernumerary stigmas sometimes as many as 6 in number, were the commonest feature. Two ovaries were also found in one case, one arising below the other. In two cases, for the first time, spores were found to have been formed on sporophorelike structures consisting of a thick hyphal strand with a globular or reniform head very much resembling a conidiophore of *Rhizopus stolonifer* or *Eurotium*. These came out of ovary-walls.

(d) Thalamus was not much affected till essential parts were more or less completely done away with. It was either modified into a small whip-like sorus or showed irregular branching with pubescence at nodes. At the tips of its branches, there were often a pair of empty glumes forming a urceolate-tubular structure. In one case it bifurcated to bear two florets, though very much degenerated.

(e) Glumes were the most stable of all floral parts. Proliferation and reduction in size were rarely met with, while in no case they were found to have been suppressed. Their reaction to smut, when exhibited, very often manifested itself by elongation and conversion into green foliar structures upto 2-3″ long with rudimentary differentiation into a sheath and blade.

4. Among abnormal smut galls, three cases of paired terminal whips are described. They represented three grades of excitation : strong, resulting in abrupt bifurcation of apical meristem ; weak, having to act for long duration to split the terminal meristem ; and an intermediate dividing it neither too quickly nor too slowly. Formation of spores in a free midrib was recorded for the first time.

5. The physical presence of the mycelium of the pathogen did not appear to be the cause of these modifications in various organs of the host.

6. The morphological nature of a normal smut-whip is discussed. The probability of its being a stem appears to be greater than that of its being an inflorescence, when the short-photoperiodic nature of sugarcane plant, and the potency of phasic reversal by summer days at the time of its commonest occurrence are taken into consideration. The analogy with cereal smuts does not hold good because unlike them, the formation of spores in the case of sugarcane smut is not confined to inflorescence only.

ACKNOWLEDGMENT

The work was carried out at the Central Sugarcane Research Station, jointly financed by Bihar Government and the Indian Central Sugarcane Committee to whom grateful thanks are due. The author is also indebted to Mr. K.L. Khanna, Director, Sugarcane Research and Development, Bihar for kindly affording facilities for and his keen interest and helpful suggestion in this work. Assistance rendered by Mr. Harish Chandra Jha, in routine observations and by Mr. Gauri Shankar Lal, Artist-photographer, in preparing the illustration is thankfully acknowledged.

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DISCUSSION

The Chairman observed that normally *Eurotium* and *Aspergillus* like conidiophores could not be expected in a smut fungus. He therefore, suggested that the observations made in the paper needed further checking up.

In the absence of the author the following paper was presented by Dr. H. M. Tysdal.

Paper

APPARENT RESISTANCE TO RATOON STUNTING DISEASE

Edwin H. Todd
Field Crops Research Branch, ARS, U.S. Department of Agriculture, Maryland, U. S. A.

INTRODUCTION

Emphasis has been placed on the use of hot water (3) and hot air (4) treatments for the control of ratoon stunting disease of sugarcane, which is believed to be caused by a virus. However, no information with regard to varietal resistance to the disease has heretofore been reported, although the need for resistance to ratoon stunting was recognized at the outset.

The present study conducted at Canal Point, Florida, attempts to demonstrate that certain varieties of sugarcane may be carriers of the ratoon stunting disease, or resistant or immune to it.

MATERIALS AND METHODS

A large number of varieties of sugarcane at Canal Point were inoculated with the ratoon stunting disease infectious agent in 1954 by Mr. C. O. Grassl, botanist, U. S. Department of Agriculture. Based on observations in this inoculation test, and also in other plantings, several of the varieties did not exhibit the internal nodal symptoms (3) characteristic of the disease. Thus, resistance of some type to the disease, as it is presently known, was indicated. In order to determine why certain varieties failed to exhibit typical vascular bundle discoloration, it was necessary to conduct an inoculation study with juice of the symptomless varieties involved.

The methods used in the inoculation study were as follows. By means of pliers, juice was squeezed from stalks of each of the 9 selected symptomless varieties, into appropriately labelled beakers. After sufficient juice from a given variety had been extracted, the pliers were dipped into 60% alcohol. The workers involved also washed their hands in 60% alcohol. C.P. 34-79 and F. 31-962, which, when infected, readily manifest nodal symptoms of the disease, were used as suscepts in the test. Two kinds of plant cane of the 2 suscepts were tested : (a) Seed pieces which were given the hot-water stimulation treatment (52° C. for 20 min.), and (b) seed pieces which were given a 2-hour hot-water treatment at 50°C. Cuttings used for (a) and (b) were obtained from material which had received the long hot-water treatment (50°C. for 2 hours) in 1954. As previously described (2), inoculation was accomplished by dipping freshly cut single-eye seed pieces of the suscepts in the juice of the symptomless varieties used. Following treatment, single-eye plantings were made February 1, 1955, in the greenhouse in 4-inch paper pots containing steamed soil. On February 18 the plants were transferred to the field. The plots in the field consisted of 6 replications (stools) per treatment placed 3 feet apart with 6 feet between treatments and 10 feet between rows. The test consisted of 9 test varieties (sources of inoculum) plus C.P. 34-79 as a control, 2 suscepts, 4 treatments, and 6 replications.

In order to obtain a more comprehensive evaluation of the test varieties, they were again inoculated at the time of conducting the experiment with juice from C.P. 34-79 which was severely affected by the ratoon stunting disease.

Ratoon stunting disease determinations were made August 30, 1955, approximately 7 months after planting, on stalks of about the same age group. Fifteen stalks per treatment were examined for the disease. Two stalks from each of 6 stools comprising a treatment plus 3 additional stalks selected at random within the treatment were examined for fibrovascular tissue discoloration.

RESULTS

TABLE I

PERCENTAGE OF PLANTS THAT EXPRESSED NODAL SYMPTOMS OF THE RATOON STUNTING DISEASE

Varieties used as source of inoculum[1]	Hot water treatment of suscept variety before inoculation			
	2 hours at 50°C.		20 minutes at 52°C.	
	Inoculated Percent	non-inoculated Percent	Inoculated Percent	non-inoculated Percent
	C. P. 34-79 used as the suscept variety			
B. 39246	0	0	13	0
Ba. 11569	0	0	20	0
C. P. 1	0	0	0	0
Cl. 41-70	0	0	0	0
Lataria	100	0	100	0
Agoule 1	100	0	100	0
96 NG 24	100	0	100	0
N. C. 116	100	0	100	0
Saharanpur Black	100	0	100	0
U. S. 54-8[2]	0	—	—	—
C. P. 34-79 (Control)	100	—	100	—
	F. 31-962 used as the suscept variety			
B. 39246	20	0	0	0
Ba. 11569	0	0	0	0
C. P. 1	0	0	0	27
Cl. 41-70	30	0	0	0
Lataria	100	0	87	13
Agoule 1	100	0	100	20
96 NG 24	100	13	67	13
N. C. 116	100	0	100	0
Saharanpur Black	100	0	100	13

[1] Stalks of these varieties used, came from material that had been inoculated with the ratoon stunting disease in 1954.

[2] This variety is a seedling which displayed what was thought to be extreme RSD symptoms and was included in this test as a possible excellent symptom expressor (suscept) to be used in future experiments.

TABLE II

PERCENTAGE OF PLANTS OF RE-INOCULATED TEST VARIETIES THAT EXPRESSED NODAL SYMPTOMS OF THE RATOON STUNTING DISEASE[1]

Variety	Nodal symptoms of ratoon stunting disease Percent
B. 39246	0
Ba. 11569	0
C. P. 1	0
Cl. 41-70	0
Lataria	0
Agoule 1	0
96 NG 24	100
N. C. 116	0
Saharanpur Black	100
C. P. 34-79 (Control)	100

[1] Juice from ratoon stunting diseased C. P. 34-79 was used for re-inoculating the test varieties.

DISCUSSION

As indicated in the data presented in Tables I and II, Saharanpur Black and 96 NG 24 apparently were inoculation " escapes " in 1954 and on re-inoculation exhibited nodal symptoms of the ratoon stunting disease.

N. C. 116, Agoule 1, and Lataria remained symptomless when re-inoculated (Table II) but, when the juice of these varieties was inoculated into the known suscepts, C. P. 34-79 and F. 31-962, the symptoms of the ratoon stunting disease were clearly evident (Table I). These results indicate that the above varieties are symptomless carriers of the disease.

Table I shows that suscepts inoculated with juice from C. P. 1 disclosed no nodal symptoms of ratoon stunting, although 2 stools of the non-inoculated controls of previously hot-water treated suscept material did exhibit vascular bundle discoloration characteristic of the disease. On re-inoculation (Table II) C. P. 1 remained free from nodal symptoms of the disease. Considering the scope of observations and the present study of the ratoon stunting disease, there is a strong indication that immunity to the disease may exist in C. P. 1.

B. 39246, Ba. 11569, and Cl. 41-70 failed to register symptoms of the ratoon stunting disease when re-inoculated (Table II). Presumably disease-free C.P. 34-79 and F. 31-962 inoculated with juice of the former varieties gave, respectively 33%, 20%, and 30% positive reactions to the disease (Table I). These results indicate that actual transmission was accomplished but that an apparently high degree of resistance to the disease exists in B. 39246, Ba. 11569, and Cl. 41-70. However, because of similar positive reactions found in the non-inoculated controls, it is a matter of conjecture to attempt to explain the reactions obtained.

Possible explanations would be that the disease was transmitted by one means or another after planting, or perhaps the material was diseased when planted. Was the disease transmitted after planting? Unauthorized cutting with contaminated implements or actual transmission by some unknown biological vector could have conceivably transmitted the disease. Was the material diseased before planting? It is more than likely that some of the material used from previously hot-water treated cane (1954) was treatment escapes or became infected in the field prior to selection for use in the present test. The majority of infected stalks observed in non-inoculated material, and the infrequent occurrence of the disease in material inoculated with juice from B. 39246, Ba. 11569, and Cl. 41-70, were found to be in stools from previously treated material. In view of the efficacy of the inoculation techniques, as demonstrated by the controls of the inoculation and re-inoculation tests, it is assumed that there were few inoculation escapes in this study.

On inoculation with juice from the seedling U. S. 54-8, the suscept variety (C.P. 34-79) remained free from the ratoon stunting disease (Table I). This is of interest in that it brings forth the observation that certain varieties may exhibit natural vascular bundle discoloration that is not distinguishable from the nodal symptoms of the ratoon stunting disease.

As reported by Abbott (1), it was observed that in several instances the more mature stalks showed ratoon stunting nodal symptoms clearly while in the younger stalks of the same stool the disease symptoms were not always apparent.

Based on the observations presented herein, the significance of this paper to the breeding programmes is, of course, that resistance in sugarcane to the ratoon stunting disease apparently does exist among certain varieties.

Another aspect that is regarded as fundamentally important is that the need for a more definitive and rapid means of diagnosing the presence of the ratoon stunting disease is further emphasized. The present method of identifying the disease by the presence of nodal tissue discoloration has been extremely valuable ; however, the finding that certain varieties may be symptomless carriers of the disease and that other varieties may possess natural fibrovascular tissue discoloration characteristic of the disease, infinitely complicates reliable determiation of the presence of the disease by the techniques now employed.

SUMMARY

A ratoon stunting disease inoculation test was conducted by injecting juice from symptomless varieties of sugarcane into single-eye cuttings of disease-free but known suscepts, C. P. 34-79 and F. 31-962. The results obtained indicated that three varieties, N. C. 116, Lataria, and Agoule 1, are symptomless carriers

of the disease. The response of B. 39246, Ba. 11569, and Cl. 41-70 ranged from an apparent resistance to what appeared to be immunity, while in C. P. 1 immunity to the ratoon stunting disease was strongly indicated.

U. S. 54-8, a seedling, exhibited natural vascular bundle discoloration which was not discernible from the nodal symptoms that characterize the ratoon stunting disease.

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A Revised Listing

OF

SUGAR CANE DISEASES AND THEIR WORLD DISTRIBUTION

Prepared by

THE STANDING COMMITTEE SUGAR CANE DISEASES
I. S. S. C. T.—1956 Congress

A REVISED LISTING OF SUGAR CANE DISEASES AND THEIR WORLD DISTRIBUTION

A paper entitled " Sugar Cane Diseases and Their World Distribution " was prepared and presented by J. P. Martin at the Seventh Congress of the I. S. S. C. T. in Brisbane, Australia (1950). It was realized at the time that the listing of sugar cane diseases as presented was incomplete. References to the occurrence of diseases in some countries were not available and in a few areas no complete disease survey had been made. For a check-list of cane diseases which would be of the greatest value to all concerned, the Plant Pathology Section recommended to the Society that : (1) a Standing Committee be appointed by the General Chairman to maintain a current listing of all sugar cane diseases of the world, (2) this information be made available to all cane-sugar producing countries, and (3) the Standing Committee report on this project at each future Congress.

As a result of this recommendation the following resolution was adopted at the Plenary Session of the 1950 Congress :

RESOLUTION—SECTION ON CANE DISEASES

" Whereas, a listing of sugar cane diseases and their world distribution was presented at the 7th Congress, and

Whereas there now exists some confusion relative to the nomenclature of diseases in the various countries,

Now, therefore, be it resolved that,

(1) A standing committee be appointed for the purpose of maintaining a current listing of all cane diseases of the world and reported upon at each future Congress. The Section on Cane Diseases recommends the following to serve on this Committee—C. G. Hughes (Australia), T. T. Lo (Formosa), J. P. Martin, Chairman (Hawaii), E. B. Martyn (Jamaica), J. W. Hes (Java), G. Orian (Mauritius), G. O. Ocfemia (Philippines), L. A. Alvarez (Puerto Rico), A. McMartin (South Africa) and E. V. Abbott (United States).

(2) The Chairman of the "Standing Committee" may increase this Committee with the approval of the General Chairman of the Society, and

(3) All matters relative to nomenclature be referred to the "Standing Committee " for appropriate action."

Subsequent to 1950 the Standing Committee made a number of amendments, either as deletions or additions, to the original listing as published, and submitted the listing for further consideration to those pathologists attending the Plant Pathology Section of the 1953 Congress held in the British West Indies. Realizing that the listing was still incomplete it was recommended that the Society appoint a new Standing Committee or reappoint the present one for the purpose of completing the check list and submitting it to the 1956 Congress for publication. Additions to the original Standing Committee were appointed at the 1953 Congress as shown on page 1179.

A current or up-to-date listing of sugar cane diseases and their world distribution is invaluable to countries in relation to interchange of varieties, disease control, and collecting expeditions, and also to universities and other scientific institutions.

Sugar cane diseases are not static. They are transmitted from place to place and from country to country chiefly by man and insects, or by the cuttings themselves. A disease reported in a country for the first time may have existed there for several years or more in a latent or inconspicuous form either on cane or on an alternate host. Where a disease has not been observed in a country for several years, it is so indicated in Part I of the present listing by an asterisk accompanied with a foot note reading, " Not observed in recent years."

The various cane-sugar producing countries of the world are listed in Table I, and again, by their geographical locations, in Table II. The latter grouping with the page reference to each country in Part II is somewhat artificial, since an effort has been made to reduce the groupings to a minimum. A number of locations where sugar cane is not grown commercially are included, as it seems highly advisable to list those areas where cane diseases are known to occur. This is particularly the situation in the " Pacific Ocean Areas " where expeditions have been made to different islands for collecting and studying wild canes and where cane diseases have been recorded.

The revised listing of sugar cane diseases, as in the original paper, is arranged in two parts :

Part I. A Check List of the Sugar-Cane Diseases of the World, the Cause of Each, and the Countries in Which Each Disease Occurs.

Part II. The Cane-Sugar Producing Countries of the World and the Diseases Occurring in Each Country.

The present listing of sugar cane diseases and their world distribution is a reference which can be used by research workers throughout the world. Amendments to the listing should be made in the future by a standing committee in order to maintain a current listing. It was suggested that it might be well to indicate or separate the major diseases from the minor. Inasmuch as a serious disease in one country is often of little importance in another country no attempt was made to separate the two groups of diseases. However, the major diseases for any country may be underlined in Part II where the diseases for each country are listed if an individual wishes to do so.

The Chairman of the Standing Committee takes this opportunity to thank each member of the Committee and all others who have so willingly cooperated on this very worthwhile project. It is with deep regret that we record the death of R. E. D. Baker on November 19, 1954.

Standing Committee
Sugar Cane Diseases and Their World Distribution,
I.S.S.C.T., 1956 Congress

J. P. Martin, (Chairman) Hawaii
E. V. Abbott, United States
L. A. Alvarez, Puerto Rico
S. C. Arruda,** Brazil
R. E. D. Baker,* B.W.I.
B. A. Bourne,** Florida, U.S.
B. L. Chona,* India
J. W. Hes, Java
C. G. Hughes, Australia
T. T. Lo, Taiwan
A. McMartin, South Africa
G. O. Ocfemia, Philippines
G. Orian, Mauritius
P. E. Robinson,** Fiji
E. M. Summers,** Cuba
* Appointed 1952
** Appointed 1953

February 17, 1955

TABLE I

CANE-SUGAR PRODUCING COUNTRIES OF THE WORLD

Andaman Islands
Angola
Antigua
Argentina
Australia

Barbados
Belgian Congo
Borneo
Brazil
British Guiana
British Honduras
Burma

Cameroons
Ceylon
Chile
China
Colombia
Costa Rica
Cuba

Dominican Republic
Dutch Guiana (Surinam)
Ecuador

Egypt
El Salvador

Fiji
Formosa (Taiwan)

Grenada
Guadeloupe
Guam
Guatemala

Haiti
Hawaii
Honduras

India
Indo China (French)
Italy

Jamaica
Japan
Java

Kenya

Madagascar
Madeira
Malay States
Martinique
Mauritius
Mexico

Montserrat
Mozambique

New Britain
New Caledonia
New Guinea
Nicaragua
Nyasaland

Okinawa (Ryukyu)

Pakistan
Panama
Paraguay
Peru
Philippines
Portugal
Puerto Rico
Reunion

Samoa
Siam (Thailand)
Sierra Leone
Solomon Islands
Southern Rhodesia
Spain

St. Croix
St. John
St. Kitts and Nevis
St. Lucia
St. Thomas
St. Vincent
Sumatra

Tahiti
Tanganyika
Trinidad and Tobago
Turkey

Uganda
Union of South Africa
United States
Florida
Louisiana
Venezuela

TABLE II

A GEOGRAPHICAL GROUPING OF THE CANE PRODUCING COUNTRIES WITH PAGE REFERENCE TO EACH COUNTRY IN PART II

- AFRICA—1197
  - Angola—1197
  - Belgian Congo—1197
  - Cameroons—1197
  - Egypt—1197
  - Kenya—1197
  - Mozambique—1197
  - Nyasaland—1197
  - Sierra Leone—1197
  - Southern Rhodesia—1197
  - Tanganyika—1197
  - Uganda—1197
  - Union of South Africa (Natal)—1197-1198
- AMERICA, NORTH AND CENTRAL—1198
  - British Honduras—1198
  - Costa Rica—1198
  - El Salvador—1198
  - Guatemala—1198
  - Honduras—1198
  - Mexico—1198
  - Nicaragua—1198
  - Panama—1198
  - United States—1198
  - Florida
  - Louisiana
- AMERICA, SOUTH—1199
  - Argentina—1199
  - Brazil—1199
  - British Guiana (Demerara)—1199
  - Chile—1199
  - Colombia—1199
  - Dutch Guiana (Surinam)—1199
  - Ecuador—1199
  - Paraguay—1199
  - Peru—1199
  - Venezuela—1199
- ASIA—1200
  - Burma—1200
  - Ceylon—1200
  - China—1200
  - India—1200
  - Indo China (French)—1200
  - Japan—1200
  - Malay States—1200
  - Pakistan—1200
  - Siam (Thailand)—1200
- EUROPE—1200
  - Italy—1200
  - Madeira—1200
  - Portugal—1201
  - Spain—1201
  - Turkey—1201
- INDIAN OCEAN AREAS—1201
  - Andaman Islands—1201
  - Java—1201
  - Madagascar—1201
  - Mauritius—1201
  - Reunion—1201
- PACIFIC OCEAN AREAS—1201
  - Australia—1201-1202
  - Borneo—1202
  - Fiji—1202
  - Formosa (Taiwan)—1202
  - Guam—1202
  - Hawaii—1202
  - New Britain—1202
  - New Caledonia—1202
  - New Guinea—1203
  - Okinawa (Ryukyu)—1203
  - Philippines—1203
  - Samoa—1203
  - Solomon Islands—1203
  - Sumatra—1203
  - Tahiti—1203
- WEST INDIES—1203
  - Antigua—1203
  - Barbados—1203
  - Cuba—1203
  - Dominican Republic—1204
  - Grenada—1204
  - Guadeloupe—1204
  - Haiti—1204
  - Jamaica—1204
  - Martinique—1204
  - Montserrat—1204
  - Puerto Rico—1204
  - St. Croix—1204
  - St. John—1204
  - St. Kitts and Nevis—1204
  - St. Lucia—1205
  - St. Thomas—1205
  - St. Vincent—1205
  - Trinidad and Tobago—1205

PART I

A CHECK LIST OF THE SUGAR CANE DISEASES OF THE WORLD, THE CAUSE OF EACH, AND THE COUNTRIES IN WHICH EACH DISEASE OCCURS

Disease	Cause	Country	
Arrow rot (Pokkah boeng?)	*Fusarium* spp.	Mauritius Union of South Africa	
Bacterial stem rot	*Erwinia sacchari* Roldan	Philippines	
Baker's leaf spot	*Bakerophoma sacchari* Died.	China Philippines	
Banded chlorosis (cold, or sectional chlorosis)	Physiological (low or high temperatures)	Australia Brazil Cuba Formosa Hawaii India	Jamaica Japan Mexico Okinawa Union of South Africa United States
Banded sclerotial (leaf) disease	*Mycelia sterilia* (in Australia)	Australia Fiji Formosa	Java New Guinea Okinawa
	Hypochnus (*Corticium*) *sasakii* Shirai (in India)	India	Philippines
	Rhizoctonia solani Kuehn (in Siam)	Siam	United States
Black leaf spot	*Phyllachora sacchari* P. Henn.	Argentina India	Java Philippines
Black rot	*Ceratostomella adiposum* (Butler) Sartoris	Australia (N.S.W.) Brazil Dominican Republic Formosa India	Java Peru United States
Black spot	*Cercospora acerosum* Dickoff et Hein	Java	Philippines
Black stripe	*Cercospora atrofiliformis* Yen, Lo et Chi	Formosa	
Brown spot	*Cercospora longipes* Butler	Argentina Brazil Colombia	Peru Philippines Puerto Rico

Disease	Cause	Country	
Brown Spot (cont.)	*Cercospora longipes* Butler	Cuba India Jamaica Java Madagascar Mauritius Mexico Nicaragua Nyasaland	Reunion Southern Rhodesia Tanganyika Uganda Union of South Africa United States Venezuela
Brown stripe	*Cochliobolus stenospilus* (Carp.) Matsumoto et Yamamoto *Helminthosporium stenospilum* (Drechsler)	Australia Brazil Cuba Dominican Republic Formosa Hawaii Fiji India ?	Jamaica Japan Mozambique Peru ? Puerto Rico Samoa Union of South Africa United States
Bud proliferation (See malgrowths)			
Bunga (bulaklak)	*Aeginetia indica* L.	Formosa India	Java Philippines
Bunch top (See malgrowths)			
Cane-killing weed	*Striga* spp.	Australia India Madagascar	Mauritius Nyasaland Union of South Africa
	Thesium australe R. Br.	Australia	
Cephalosporium seed rot	*Cephalosporium sacchari* Butler *Fusarium moniliforme* Sheldon	United States	
Chlorosis	Iron deficiency		
Limestone		Antigua Hawaii Fiji	Jamaica Union of South Africa
Ratoon (Iron chlorosis)		Australia Fiji Hawaii Jamaica	Peru Union of South Africa
Chlorotic leaf blotch	Undetermined	Guam Hawaii Guadeloupe	United States (Louisiana) Peru

Disease	Cause	Country	
Chlorotic streak	*Virus*	Australia British Guiana Colombia Dutch Guiana Fiji Formosa Grenada Guadeloupe Hawaii Jamaica	Java Martinique Mauritius Puerto Rico St. Lucia Samoa Trinidad Turkey Union of South Africa United Sates (Louisiana)
Cluster Stool (See malgrowths)			
Collar rot	*Hendersonina sacchari* Butler	Argentina India Indo China	Mauritius Philippines
Culm and midrib rot	*Papularia vinosa* (Berk. et Curt.) Mason	Philippines	
Diplodia rot	*Diplodia* sp.	Puerto Rico Union of South Africa	
Downy mildew	*Sclerospora sacchari* Miy.	Australia* Fiji Formosa India	Japan New Guinea Philippines Siam
Droopy top	Copper deficiency	Australia	United States (Florida)
Dry rot	*Physalospora rhodina* (Berk. et Curt.) Cke.	Barbados Brazil British Guiana Cameroons Cuba Dominican Republic India Indo China	Jamaica Java Malay States Mexico Philippines Puerto Rico St. Thomas Trinidad and Tobago
Dry top rot	*Plasmodiophora vascularum* Matz	Puerto Rico	Venezuela
Dwarf disease	Virus	Australia	
Ergot	*Claviceps* sp.	Philippines ?	

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*Not observed in recent years.

Disease	Cause	Country	
Eye spot	*Helminthosporium sacchari*(v. Breda de Haan) Butler	Andaman Islands Antigua Argentina Australia Barbados Belgian Congo Brazil Br. Guiana British Honduras Cameroons China Colombia Costa Rica Cuba Dominican Republic Dutch Guiana Egypt Fiji Formosa Grenada Guadeloupe Haiti Hawaii Honduras India Indo China Italy	Jamaica Japan Java Kenya Madagascar Madeira Malay States Martinique Mauritius Mexico Mozambique New Guinea Okinawa Peru Philippines Puerto Rico Reunion St. Kitts and Nevis St. Lucia St. Thomas Siam Sierra Leone Tanganyika Trinidad and Tobago Uganda Union of South Africa United States (Florida) Venezuela
Fiji disease	*Virus*	Australia Fiji Madagascar New Britain New Caledonia	New Guinea Philippines Samoa Solomon Islands
Fusarium sett or stem rot	*Fusarium* sp. and *Fusarium moniliforme* (Sheldon) Snyd. et Hans.	Union of South Africa United States	
Gangrene	*Aspergillus, Penicillium* spp.	Union of South Africa	

Disease	Cause	Country	
Growth-retarding disease (See ratoon stunting)			
Gumming disease	*Xanthomonas vasculorum* (Cobb) Dows.	Antigua* Australia* Barbados* Brazil British Honduras* Colombia Dominican Republic Fiji* Guadeloupe*	Madagascar Madeira Martinique* Mauritius New Guinea ? Puerto Rico* Reunion St. Kitts & Nevis* St. Lucia* St. Vincent*
Iliau	*Gnomonia iliau,* Lyon	Australia Brazil* Cuba*	Hawaii* Philippines ?* United States*
Inflorescence binding fungus	*Ephelis pallida*	Union of South Africa	
Internal stalk necrosis	Undetermined	Formosa Hawaii Mauritius	United States (Louisiana)
Kalimati	Physiological	Java	
Knife cut (See malgrowths)			
Leaf and sheath rot	*Marasmius plicatus* Wakker	Philippines	
Leaf blast	*Didynosphaeria taiwanensis* Yen et Chi	Formosa	
Leaf blight	*Leptosphaeria taiwanensis* Yen et Chi	Formosa Okinawa	
Leaf buckle	Mechanical	Australia Fiji Formosa Hawaii	Mauritius Union of South Africa United States
Leaf burn	Physiological	Australia Fiji Formosa Guam Hawaii	Mauritius Philippines United States (Florida)

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*Not observed in recent years.

Disease	Cause	Country	
Leaf fleck	Undetermined	Fiji Formosa Hawaii	Mauritius Union of South Africa
Leaf freckle	Undetermined	Australia Fiji Guam Hawaii	Nyasaland Union of South Africa United States
Leaf scald	*Bacterium albilineans* Ashby	Australia Brazil British Guiana Dutch Guiana Fiji Formosa	Hawaii Indo China Java Madagascar Mauritius Philippines Reunion
Leaf sheath adhesion	Unknown	Mauritius	
Leaf scorch	*Stagonospora sacchari* Lo & Ling	Formosa	Philippines
Leaf splitting disease	*Mycosphaerella striatiformans* Cobb	Fiji Hawaii	Java
	Sclerospora northii Weston	Fiji	
Leaf stipple	Undetermined	Guam Hawaii Java	Union of South Africa United States
Leafy tuft (See malgrowths)			
Lightning injury	Elemental	Australia British Guiana Fiji Hawaii	Mauritius Puerto Rico Union of South Africa United States
Limestone chlorosis (See Chlorosis)			
Malgrowths	Undetermined		
Bud proliferation		Mauritius	
Bunch top (Witches' broom)		Hawaii Mauritius	Union of South Africa

Disease	Cause	Country
Malgrowths (*cont.*)		
Cluster stool		Australia Cuba Fiji Peru
Knife cut		Australia Guam Hawaii Mauritius Union of South Africa
Leafy tuft		India
Multiple buds		Cuba Fiji Hawaii Mauritius Union of South Africa United States
Stem Galls		Australia Cuba Fiji Formosa Guam Hawaii Java Mauritius Philippines Puerto Rico Union of South Africa
Tangle top (twisted top)	Mechanical	Australia Brazil Cuba Fiji Formosa Guam Hawaii India Japan Mauritius Nyasaland Okinawa Peru Philippines Puerto Rico Southern Rhodesia Union of South Africa United States
Witches' broom (Same as bunch top ?)	Undetermined	Australia Mauritius
Manganese deficiency (See Pahala blight)		
Marasmius sheath and shoot rot	*Marasmius stenophyllus* Mont.	United States*
Midrib blotch	Undetermined	Hawaii Union of South Africa
Mosaic	*Virus*	Andaman Islands Angola Argentina Australia Barbados Belgian Congo Fiji* Formosa Guadeloupe Haiti Hawaii Honduras India Indo China Okinawa Paraguay Peru Philippines Puerto Rico Reunion St. Kitts and Nevis

*Not observed in recent years.

Disease	Cause	Country		
Mosaic	*Virus*	British Honduras Cameroons China Colombia Costa Rica Cuba Dominican Republic Dutch Guiana Egypt El Salvador	Italy Jamaica Japan Java Kenya Madagascar Madeira Malay States Martinique Mexico New Guinea Nicaragua Nyasaland	St. Thomas Siam Sierra Leone Tanganyika Trinidad and Tobago Turkey Uganda Union of South Africa United States Venezuela
Mottled stripe	*Xanthomonas rubrisubalbicans* Christopher et Edgerton	Australia Colombia Fiji Guadeloupe	Jamaica Martinique Nicaragua Peru	Puerto Rico Union of South Africa United States
Multiple buds (See malgrowths)				
Myriogenospora leaf binding	*Myriogenospora* sp.	Argentina Brazil	United States (Louisiana)	
Pahala blight	Manganese deficiency	Fiji Formosa Hawaii Jamaica	Samoa United States (Florida)	
Pestalozzia leaf spot	*Pestalozzia fuscescens* sor. var. *sacchari* Wakker	Australia (Q)* Cuba India	Java Mauritius Philippines	
Phyllosticta spot (leaf)	*Phyllosticta hawaiiensis* Caum	Hawaii Philippines	Puerto Rico	
	(*Phyllosticta sorghina* Sacc.) (*Phyllosticta sacchari* Speg.)		United States (Florida)	
	Phyllosticta spp.	Union of South Africa		
Phytophthora rot of cuttings	*Phytophthora* spp.	United States (Louisiana)		

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*Not observed in recent years.

Disease	Cause	Country
Pineapple disease	*Ceratostomella paradoxa* (de Seynes) Dade	Antigua Argentina Australia Barbados Brazil Br. Guiana British Honduras Colombia Costa Rica Cuba Dominican Republic Egypt Fiji Formosa Guadeloupe Hawaii India Indo China Jamaica Japan Java Madagascar Madeira ? Mauritius Mexico New Guinea Nicaragua Okinawa Paraguay Philippines Puerto Rico Reunion St. Kitts and Nevis St. Lucia Trinidad and Tobago Union of South Africa United States Venezuela
Pokkah boeng	*Gibberella fujikuroi* (Saw.) Wr. (*Fusarium moniliforme* Sheldon) *Gibberella moniliforme* Wineland)	Andaman Islands Angola Antigua Argentina Australia Barbados Belgian Congo Brazil British Guiana British Honduras Cameroons China Colombia Cuba Dominican Republic Dutch Guiana Egypt Fiji Formosa Grenada Guadeloupe Guam Haiti Hawaii Honduras India Indo China Italy Jamaica Japan Java Kenya Madagascar Madeira Malay States Martinique Mauritius Mexico New Guinea Nicaragua Okinawa Paraguay Peru Philippines Puerto Rico Reunion St. Kitts and Nevis St. Lucia St. Thomas Samoa Siam Sierra Leone Tanganyika Trinidad and Tobago Uganda Union of South Africa United States Venezuela
Powdery mildew	*Erysiphe graminis* DC.	Italy
Ratoon chlorosis (See Chlorosis)		

Disease	Cause	Country		
Ratoon stunting disease (Q. 28 disease, stunting disease, growth retarding disease)	Undetermined	Antigua Australia Barbados Colombia Cuba Fiji Formosa	Hawaii India Jamaica Mexico Mauritius Nicaragua Philippines	Puerto Rico St. Kitts and Nevis Trinidad Union of South Africa United States (Fla. and La.)
Red leaf spot (purple spot)	*Eriosphaeria sacchari* (v. Breda de Haan) Went		Cuba Formosa	Java Trinidad
Red line disease (stem red stripe)	*Fusarium* sp.		Formosa	
Red rot	*Physalospora tucumanensis* (Went) Speg. (*Colletotricum Falcatum* Went)	Angola Antigua Argentina Australia Barbados Brazil British Guiana British Honduras China Colombia Cuba Dominican Republic Egypt El Salvador	Fiji Formosa Guadeloupe Guam Haiti Hawaii India Indo China Jamaica Japan Java Madagascar Madeira Malay States Mauritius Mexico Mozambique	New Guinea Nicaragua Okinawa Peru Philippines Puerto Rico Reunion St. Kitts and Nevis St. Lucia Samoa Siam Trinidad and Tobago Union of South Africa United States
Red rot of leaf sheath	*Sclerotium rolfsii Sacc.*	Australia Brazil Cuba Fiji Formosa India	Java Mexico New Guinea Okinawa Peru Philippines	Puerto Rico Trinidad Union of South Africa United States

Disease	Cause	Country
Red spot of leaf sheath	*Cercospora vaginae* Krueger	Argentina Barbados Brazil British Guiana China Colombia Cuba Dominican Republic Formosa Haiti Hawaii ? Honduras India Indo China Jamaica Japan Java Mauritius Mexico Okinawa Peru Philippines Puerto Rico Reunion Siam Trinidad* and Tobago Union of South Africa United States
Red stripe	*Xanthomonas rubrilineans* (Lee et al) Starr et Burkh.	Argentina Australia Barbados British Guiana Brazil Cuba Dutch Guiana Formosa Guadeloupe Guam Hawaii India Indo China ? Jamaica Java Kenya Martinique Mexico Nicaragua Okinawa Philippines Puerto Rico Trinidad Uganda Union of South Africa United States
Rhizoctonia sheath and shoot rot	*Rhizoctonia solani* Kuehn	United States
Rind disease	*Pleocyta sacchari* (Mass.) Petr. et Syd. (*Melanconium Sacchari* Mass.)	Andaman Islands Angola Antigua Australia Barbados Brazil British Guiana British Honduras China Colombia Cuba Dominican Republic Egypt Fiji Formosa Guadeloupe Haiti Hawaii India Indo China Jamaica Japan Java Madagascar Malay States Mauritius Mexico New Guinea Okinawa Paraguay Peru Philippines Puerto Rico Reunion St. Kitts and Nevis St. Luica Trinidad and Tobago Uganda Union of South Africa United States
Ring mosaic	*Virus* ?	Java United States

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*Not observed in recent years.

Disease	Cause	Country
Ring spot	*Leptosphaeria sacchari* v. Breda de Haan (*Phyllosticta saccharicola* Henn.)	Andaman Islands Angola Antigua Argentina Australia Barbados Belgian Congo Barzil British Guiana British Honduras China Colombia Costa Rica Cuba Dominican Republic Dutch Guiana Egypt El Salvador Fiji Formosa Guadeloupe Hawaii Honduras India Indo China Jamaica Japan Java Kenya Madagascar Martinique Mauritius Mexico Nyasaland Okinawa Paraguay Peru Philippines Puerto Rico Reunion St. Kitts and Nevis Samoa Siam Sierra Leone Tanganyika Trinidad and Tobago Uganda Union of South Africa United States Venezuela
Root rots	*Corticium* sp.	Philippines
	Dictyophora sp.	Australia* Madagascar
	Marasmius plicatus Wakker	Java Mauritius Peru Philippines
	Marasmius sacchari Wakker	Antigua Australia Barbados British Guiana Colombia Cuba Dominican Republic Fiji Formosa Grenada Guadeloupe Haiti Hawaii India Indo China Jamaica Java Martinique Mauritius Mexico Okinawa Paraguay Peru Philippines Puerto Rico St. Kitts and Nevis St. Lucia St. Vincent Trinidad and Tobago Union of South Africa United States
	Olpidium sp.	Puerto Rico
	Pythium spp.	Australia El Salvador Formosa Hawaii India Java Mauritius Mexico Philippines Union of South Africa United States
	Rhizoctonia spp.	Barbados Formosa Java Mauritius Puerto Rico Union of South Africa United States

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*Not observed in recent years.

Disease	Cause	Country
Rust	*Puccinia kuehnii* (Krueger) Butler	Australia China Cuba Fiji Formosa India Indo China Japan Java Madagascar Mozambique New Guinea Philippines Union of South Africa
Schizophyllum rot	*Schizophyllum commune* Fr.	Argentina Australia (Q) Brazil Cuba Dominican Republic Formosa Haiti Hawaii India Indo China Japan Java Madagascar Martinique Mauritius Mexico New Guinea Philippines Puerto Rico Union of South Africa United States
Sclerospora disease	*Sclerospora* sp. *Sclerophthora* sp.	Australia Mauritius Peru Union of South Africa United States (Louisiana)
Sclerotial disease (Synonomous with Sclerotium disease and red rot of sheath ?)	*Sclerotium* sp.	Australia Formosa Guam
Sclerotium disease (djamoer oepas)	*Sclerotium* sp.	Java
Sembur	Undetermined	Java
Sereh	Undetermined	Formosa Java*
Sheath rot (Cytospora sheath rot, stem canker)	*Cytospora sacchari* Butler	Argentina Australia Brazil British Guiana Cuba Fiji Formosa Hawaii India Japan Java Mexico Okinawa Peru Philippines Puerto Rico Union of South Africa United States
Smut	*Sphacelotheca cruenta* Potter	India
	Ustilago scitaminea Syd.	Argentina Belgian Congo Brazil Ceylon China Egypt Formosa India Indo China Java* Madagascar Mauritius Mozambique Okinawa Paraguay Philippines Reunion Siam Southern Rhodesia Union of South Africa

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*Not observed in recent years.

Disease	Cause	Country		
Sooty mold	*Fumago* (?) *sacchari* Speg. *Capnodium* spp.	Argentina Australia British Guiana Cuba Formosa Hawaii	India Indo China Madagascar Mauritius Okinawa Paraguay Peru	Philippines Puerto Rico Trinidad Uganda Union of South Africa United States
Stellate-crystal fungus	*Himantia stellifera* Johnston	Argentina Barbados Brazil British Guiana Cuba	Dominican Republic Hawaii Jamaica Java Madagascar	Puerto Rico St. Croix Trinidad and Tobago Union of South Africa
Stem bleeding	Undetermined	Mauritius		
Stem galls (See malgrowths)				
Stinking rot	*Pseudomonas desaiana* (Burkh.) Sarrel (*Bacterium pyocyaneum saccharum* Desai)		India	
Streak	*Virus*		Brazil ? Egypt India Madagascar Madeira Mozambique	Nyasaland Southern Rhodesia Reunion Union of South Africa
Target blotch	*Helminthosporium* sp. Priode	Cuba Union of South Africa		
Variegation, leaf and stalk	Genetical	Australia Brazil British Guiana	Colombia Fiji Formosa Hawaii	Mauritius Peru Union of South Africa
White stripe	Undetermined	Peru	United States	
Wilt	*Cephalosporium sacchari* Butler	Argentina Colombia Dominican Republic Guadeloupe India	Mexico Peru Philippines Reunion Southern Rhodesia	Uganda Union of South Africa United States
Witches' broom (See malgrowths)				

Disease	Cause	Country
Yellowing disease (Yellows or Cane Yellowing)	Potassium deficiency	Fiji
Yellow spot (leaf)	*Cercospora kopkei* Krueger	Argentina Australia Brazil China Colombia Cuba Fiji Formosa India Indo China Java New Guinea Okinawa Philippines Reunion Union of South Africa
Zonate leaf spot	*Gloeocercospora sorghi* Bain et Edgerton	United States

PART II

THE CANE-SUGAR PRODUCING COUNTRIES OF THE WORLD AND THE CANE DISEASES OCCURRING IN EACH COUNTRY

AFRICA

Angola :

Mosaic, pokkah boeng, red rot, rind disease, ring spot.

Belgian Congo :

Eye spot, mosaic, pokkah boeng, ring spot, smut.

Cameroons :

Dry rot, eye spot, mosaic, pokkah boeng.

Egypt :

Eye spot, mosaic, pineapple disease, pokkah boeng, red rot, rind disease, ring spot, smut, streak.

Kenya :

Eye spot, mosaic, pokkah boeng, red stripe, ring spot.

Mozambique :

Brown stripe, eye spot, red rot, rust, smut, streak.

Nyasaland :

Brown spot, cane-killing weed, leaf freckle, mosaic, ring spot, streak, tangle top.

Sierra Leone :

Eye spot, mosaic, pokkah boeng, ring spot.

Southern Rhodesia :

Brown spot, smut, streak, tangle top, wilt.

Tanganyika :

Brown spot, eye spot, mosaic, pokkah boeng, ring spot.

Uganda :

Brown spot, eye spot, mosaic, pokkah boeng, red stripe, rind disease, ring spot, sooty mold, wilt.

Union of South Africa (Natal) :

Arrow rot, banded chlorosis, brown spot, brown stripe, bunch top, canekilling weed, chlorotic streak, diplodia rot, eye spot, fusarium sett or stem rot, gangrene, inflorescence binding fungus, knife cut, leaf buckle, leaf fleck, leaf freckle, leaf stipple, lightning injury, limestone chlorosis, midrib blotch, mosaic, mottled stripe, multiple buds, phyllosticta spot, pineapple disease, pokkah boeng, ratoon chlorosis, ratoon stunting disease, red rot, red rot of leaf sheath, red spot of leaf sheath, red stripe, rind disease, ring spot, root rot (*Marasmius* sp., *Pythium* spp., *Rhyzoctonia* sp.,), rust, Schizophyllum rot, sclerospora disease, sheath rot, smut, sooty mold, stellate-crystal fungus, stem canker (see sheath rot), stem galls, streak, tangle top, target blotch, variegation (leaf and stalk), wilt, yellow spot.

AMERICA, NORTH AND CENTRAL

British Honduras :

Eye spot, gumming, mosaic, pineapple disease, pokkah boeng, red rot, rind disease, ring spot.

Costa Rica :

Eye spot, mosaic, pineapple disease, ring spot.

El Salvador :

Mosaic, red rot, ring spot, root rot (*Pythium* sp.).

Guatemala :

Honduras :

Eye spot, mosaic, pokkah boeng, red spot of leaf sheath, ring spot.

Mexico :

Banded chlorosis, brown spot, dry rot, eye spot, mosaic, pineapple disease, pokkah boeng, ratoon stunting disease, red rot, red rot of leaf sheath, red spot of leaf sheath, red stripe, rind disease, ring spot, root rot (*Marasmius* sp., *Pythium* sp. ?), Schizophyllum rot, sheath rot (Cytospora), wilt.

Nicaragua :

Brown spot, mosaic, mottled stripe, pineapple disease, pokkah boeng, ratoon stunting disease, red rot, red stripe.

Panama :

United States (Florida and Louisiana) :

Banded chlorosis, banded sclerotial disease, black rot, brown spot, brown stripe, cephalosporium seed rot, chlorotic leaf blotch (La.), chlorotic streak (La.), droopy top, eye spot (Fla.), fusarium sett or stem rot, iliau, internal stalk necrosis (La.), leaf buckle, leaf burn (Fla.), leaf freckle, leaf stipple, lightning injury, marasmius sheath and shoot rot, mosaic, mottled stripe, multiple buds, myriogenospora leaf binding (La.), pahala blight (Fla.), phyllosticta spot, phytophthora rot of cuttings, pineapple disease, pokkah boeng, ratoon stunting, red rot, red rot of leaf sheath, red spot of leaf sheath, red stripe, rhizoctonia sheath and shoot rot, rind disease, ring mosaic, ring spot, root rot (*Marasmius* sp., *Pythium* sp., *Rhizoctonia* spp.), schizophyllum rot, sclerospora disease (La.), sheath rot (Cytospora), sooty mold, tangle top white stripe (leaf), wilt, zonate leaf spot.

AMERICA, SOUTH

Argentina :

Black leaf spot, brown spot, collar rot, eye spot, mosaic, myriogenospora leaf binding, pineapple disease, pokkah boeng, red rot, red spot of leaf sheath, red stripe, ring spot, schizophyllum rot, sheath rot (Cytospora), smut, sooty mold, stellate-crystal fungus, wilt, yellow leaf spot.

Brazil :

Banded chlorosis, black rot, brown spot, brown stripe, dry rot, eye spot, gumming, iliau, leaf scald, myriogenospora leaf binding, pineapple disease, pokkah boeng, red rot, red rot of leaf sheath, red spot of leaf sheath, red stripe, rind disease, ring spot, schizophyllum rot, sheath rot, smut, stellate-crystal fungus, streak ?, twisted top, variegation, (leaf), yellow spot.

British Guiana (Demerara) :

Chlorotic streak, dry rot, eye spot, leaf scald, leaf variegation, lightning injury, pineapple disease, pokkah boeng, red rot, red spot of leaf sheath, red stripe, rind disease, ring spot, root rot (*Marasmius* sp.,) sheath rot, sooty mold stellate-crystal fungus.

Chile :

Colombia :

Brown spot, chlorotic streak, eye spot, gumming, mosaic, mottled stripe, pineapple disease, pokkah boeng, ratoon stunting, red rot, red spot of leaf sheath, rind disease, ring spot, root rot (*Marasmius* sp.), variegation (leaf), wilt, yellow leaf spot.

Dutch Guiana (Surinam) :

Chlorotic streak, eye spot, leaf scald, mosaic, pokkah boeng, red stripe, ring spot.

Ecuador :

Paraguay :

Mosaic, pineapple disease, pokkah boeng, rind disease, ring spot, root rot (*Marasmius* sp.), smut, sooty mold.

Peru :

Black rot, brown spot, brown stripe ?, chlorotic leaf blotch, cluster stool, eye spot, mosaic, mottled stripe, pokkah boeng, ratoon chlorosis, red rot, red rot of leaf sheath, red spot of leaf sheath, rind disease, ring spot, root rot (*Marasmius spp.*), sclerospora disease, sheath rot, sooty mold, tangle top, variegation (leaf), wilt, white stripe.

Venezuela :

Brown spot, dry top rot, eye spot, mosaic, pineapple disease, pokkah boeng, ring spot.

ASIA

Burma :

Ceylon :

Smut.

China :

Baker's leaf spot, eye spot, mosaic, pokkah boeng, red rot, red spot of leaf sheath, rind disease, ring spot, rust, smut, yellow leaf spot.

India :

Banded chlorosis, banded sclerotial disease, black leaf spot, black rot, brown spot, brown stripe ?, bulaklak (bunga), collar rot, downy mildew, dry rot, eye spot, leafy tuft, mosaic, pestalozzia leaf spot, pineapple disease, pokkah boeng, ratoon stunting disease, red rot, red rot of leaf sheath, red spot of leaf sheath, red stripe, rind disease, ring spot, root rot (*Marasmius* sp., *Pythium* sp.), rust, schizophyllum rot, sheath rot (Cytospora sheath rot, stem canker), smut, sooty mold, stinking rot, streak, striga (cane-killing weed), tangle top, wilt, yellow spot.

Indo China (French) :

Collar rot, dry rot, eye spot, leaf scald, mosaic, pineapple disease, pokkah boeng, red rot, red spot of leaf sheath, red stripe?, rind disease, ring spot, root rot (*Marasmius* sp.), rust, schizophyllum rot, smut, sooty mold, yellow leaf spot.

Japan :

Banded chlorosis, brown stripe, downy mildew, eye spot, mosaic, pineapple disease, pokkah boeng, red rot, red spot of leaf sheath, rind disease, ring spot, rust, schizophyllum rot, sheath rot (Cytospora), tangle top.

Malay States :

Dry rot, eye spot, mosaic, pokkah boeng, red rot, rind disease.

Pakistan :

Siam (Thailand) :

Banded sclerotial leaf disease, downy mildew, eye spot, mosaic pokkah boeng, red rot, red spot of leaf sheath, ring spot, smut.

EUROPE

Italy :

Eye spot, mosaic, pokkah boeng, powdery mildew.

Madeira :

Eye spot, gumming, mosaic ?, pineapple disease ?, pokkah boeng ?, red rot, streak.

Portugal :

Spain :

Turkey :

Chlorotic streak, mosaic.

INDIAN OCEAN AREAS

Andaman Islands :

Eye spot, mosaic, pokkah boeng, rind disease, ring spot.

Java :

Banded sclerotial leaf disease, black leaf spot, black rot, black spot, brown spot, bulaklak, chlorotic streak, dry rot, eye spot, kalimati, leaf scald, leaf splitting, leaf stipple mosaic, pestalozzia leaf spot, pineapple disease, pokkah boeng, red leaf spot, red rot, red rot of leaf sheath, red spot of leaf sheath, red stripe, rind disease, ring mosaic, ring spot, root rot (*Marasmius* spp., *Pythium* sp., *Rhizoctonia* rust, schizophyllum rot, sclerotium disease (djamoer oepas), sembur, sereh, sheath rot (Cytospora), smut, stellate-crystal fungus, stem galls, yellow leaf spot.

Madagascar :

Brown spot, eye spot, Fiji disease, gumming, leaf scald, mosaic, pineapple disease, pokkah boeng, red rot, rind disease, ring spot, root rot (*Dictyophora* sp.), rust, schizophyllum rot, smut, sooty mold, stellate-crystal fungus, streak, striga (cane-killing weed).

Mauritius :

Arrow rot, brown spot, bud proliferation or abnormal buds, bunch top, cane-killing weed, chlorotic streak, collar rot, eye spot, gumming, internal stalk necrosis, knife cut, leaf buckle, leaf burn, leaf fleck, leaf scald, leaf sheath adhesion, lightning injury, multiple buds, pestalozzia leaf spot, pineapple disease, pokkah boeng, ratoon stunting, red rot, red spot of leaf sheath, rind disease, ring spot, root rot (*Marasmius plicatus*, *Marasmius sacchari*?, *Pythium* sp. *Rhizoctonia* spp.), schizophyllum rot, sclerospora disease, smut, sooty mold, stem bleeding, stem galls, tangle top, veriegation (leaf and stalk), witches' broom.

Reunion :

Brown spot, eye spot, gumming, leaf scald, mosaic, pineapple disease, pokkah boeng, red rot, red spot of leaf sheath, rind disease, ring spot, smut, streak, wilt, yellow leaf spot.

PACIFIC OCEAN AREAS

Australia :

Banded chlorosis (cold chlorosis), banded sclerotial disease, black rot, brown stripe, cane-killing weeds (two), chlorotic streak, cluster stool, downy mildew, droopy top, dwarf disease, eye spot, Fiji disease, gumming, iliau, knife cut, leaf buckle, leaf burn, leaf freckle, leaf scald, lightning injury, mosaic, mottled stripe, pestalozzia leaf spot, pineapple disease, pokkah boeng, ratoon chlorosis, ratoon stunting, red rot, red rot of leaf sheath, red stripe, rind disease, ring spot, root rot (*Marasmius* sp., *Pythium* sp., *Dictyophora* sp.), rust, schizophyllum rot, sclerospora disease, sclerotial disease, sheath rot, sooty mold, stem galls, tangle top, variegation (leaf and stalk), witches' broom, yellow spot.

Borneo :

Fiji :

Banded sclerotial disease, brown stripe, chlorotic streak, cluster stool, downy mildew, eye spot, Fiji disease, gumming, leaf buckle, leaf burn, leaf fleck, leaf freckle, leaf scald, leaf splitting disease, lightning injury, limestone chlorosis, mosaic, mottled stripe, multiple buds, pahala blight, pineapple disease, pokkah boeng, ratoon chlorosis (iron), ratoon stunting, red rot, red rot of leaf sheath, rind disease, ring spot, root rot (*Marasmius* sp.), rust, sheath rot, stem galls, tangle top, variegation (leaf and stalk), yellow spot, yellowing disease.

Formosa (Taiwan) :

Banded chlorosis (cold or sectional chlorosis), banded sclerotial leaf disease, black rot, black stripe, brown stripe, bunga, chlorotic streak, downy mildew, eye spot, internal stalk necrosis, leaf blast, leaf blight, leaf buckle, leaf burn, leaf fleck, leaf scald, leaf scorch, mosaic, pahala blight, pineapple disease, pokkah boeng, purple spot (red leaf spot), ratoon stunting disease, red line disease, red rot, red rot of leaf sheath, red spot of leaf sheath, red stripe, rind disease, ring spot, root rot (*Marasmius* sp., *Pythium* sp., *Rhizoctonia* spp.), rust, schizophyllum rot, sclerotial disease, sereh, sheath rot (Cytospora). smut, sooty mold, stem galls ,tangle top (twisted top), variegation (leaf and stalk), yellow leaf spot.

Guam :

Chlorotic leaf blotch, knife cut, leaf burn, leaf freckle, leaf stipple, pokkah boeng, red rot, red stripe, sclerotial disease, stem galls, tangle top.

Hawaii :

Banded chlorosis, brown stripe, bunch top, chlorotic leaf blotch, chlorotic streak, eye spot, iliau, internal stalk necrosis, knife cut, leaf buckle, leaf burn, leaf fleck, leaf freckle, leaf scald, leaf splitting disease, leaf stipple, lightning injury, limestone chlorosis, midrib blotch, mosaic, multiple buds, pahala blight (Mn deficiency), phyllosticta spot, pineapple disease, pokkah boeng, ratoon chlorosis, ratoon stunting, red rot, red spot of leaf sheath?, red stripe, rind disease, ring spot, root rot (*Marasmius* sp., *Pythium* sp.), schizophyllum rot, sheath rot, sooty mold, stellate-crystal fungus, stem galls, tangle top, variegation (leaf and stalk).

New Britain :

Fiji disease.

New Caledonia :

Fiji disease

New Guinea :

Banded sclerotial disease, downy mildew, eye spot, Fiji disease, gumming?, mosaic, pineapple disease, pokkah boeng, red rot, red rot of leaf sheath, rind disease, rust, schizophyllum rot, yellow spot.

Okinawa (Ryukyu) :

Banded chlorosis (sectional), banded sclerotial disease, eye spot, leaf blight‘ mosaic, pineapple disease, pokkah boeng, red rot, red rot of leaf sheath, red spot of leaf sheath, red stripe, rind disease, ring spot, root rot (*Marasmius* sp.), sheath rot (Cytospora), smut, sooty mold, tangle top, yellow spot.

Philippines :

Bacterial stem rot, Baker's leaf spot, banded sclerotial leaf disease, black leaf spot, black spot, brown spot, bunga, collar rot, culm and midrib rot, downy mildew, dry rot, ergot?, eye spot, Fiji disease, iliau?, leaf and sheath rot, leaf burn, leaf scald, leaf scorch, mosaic, pestallozia leaf spot, phyllosticta spot, pineapple disease, pokkah boeng, ratoon stunting, red rot, red rot of leaf sheath, red spot of leaf sheath, red stripe, rind disease, ring spot, root rot (*Corticium* sp., *Marasmius* spp., *Pythium* sp.), rust schizophyllum rot, sheath rot (Cytospora), smut, sooty mold, stem galls, tangle top, wilt, yellow spot.

Samoa :

Brown stripe, chlorotic streak, Fiji disease, pahala blight, (Mn deficiency) pokkah boeng, red rot, ring spot.

Solomon Islands :

Fiji disease.

Sumatra

Tahiti :

WEST INDIES

Antigua :

Eye spot, gumming, limestone chlorosis, pineapple disease, pokkah boeng, ratoon stunting disease, red rot, rind disease, ring spot, root rot (*Marasmius* sp.).

Barbados :

Dry rot, eye spot, gumming, mosaic, pineapple disease, pokkah boeng, ratoon stunting disease, red rot, red spot of leaf sheath, red stripe, rind disease, ring spot, root rot (*Marasmius* sp., *Rhizoctonia* spp.), stellate-crystal fungus.

Cuba :

Banded chlorosis (cold chlorosis), brown spot, brown stripe, cluster stool, dry rot, eye spot, iliau, mosaic, multiple buds, pestalozzia leaf spot, pineapple disease, pokkah boeng, ratoon stunting disease, red leaf spot, red rot, red rot of leaf sheath, red spot of leaf sheath, red stripe, rind disease, ring spot, root rot (*Marasmius* sp.), rust, schizophyllum rot, sheath rot, (Cytospora), sooty mold, stellate-crysal fungus, stem galls, tangle top, target blotch, yellow leaf spot.

Dominican Republic :

Black rot, brown stripe, dry rot, eye spot, gumming, mosaic, pineapple disease, pokkah boeng, red rot, red spot of leaf sheath, rind disease, ring spot, root rot (*Marasmius* sp.), schizophyllum rot, stellate-crystal fungus, wilt.

Grenada :

Chlorotic streak, eye spot, pokkah boeng, root rot (*Marasmius* sp.),

Guadeloupe :

Chlorotic leaf blotch, chlorotic streak, eye spot, gumming, mosaic, mottled stripe, pineapple disease, pokkah boeng, red rot, red stripe, rind disease, ring spot, root rot (*Marasmius* sp.), wilt.

Haiti :

Eye spot, mosaic, pokkah boeng, red rot, red spot of leaf sheath, rind disease, root rot (*Marasmius* sp.), schizophyllum rot.

Jamaica :

Banded chlorosis, brown spot, brown stripe, chlorotic streak, dry rot, eye spot, limestone chlorosis, mosaic mottled stripe, pahala blight, pineapple disease, pokkah boeng, ratoon chlorosis, ratoon stunting, red rot, red spot of leaf sheath, red stripe, rind disease, ring spot, root rot (*Marasmius* sp.), stellate-crystal fungus.

Martinique :

Chlorolic streak, eye spot, gumming, mosaic, mottled stripe, pokkah boeng, red stripe, ring spot, root rot (*Marasmius* sp.), schizophyllum rot.

Montserrat :

Puerto Rico :

Brown spot, brown stripe, chlorotic streak, diplodia rot, dry rot, dry top rot, eye spot, gumming, lightning injury, mosaic, mottled stripe, phyllosticta leaf spot, pineapple disease, pokkah boeng, ratoon stunting, red rot, red rot of leaf sheath, red spot of leaf sheath, red stripe, rind disease, ring spot, root rot (*Marasmius* sp., *Olpidium* sp., *Rhizoctonia* spp.), schizophyllum rot, sheath rot (Cytospora), sooty mold, stellate-crystal fungus, stem galls, tangle top.

St. Croix :

Stellate-crystal fungus.

St. John :

St. Kitts and Nevis :

Eye spot, gumming, mosaic, pineapple disease, pokkah boeng, ratoon stunting, red rot, rind disease, ring spot, root rot (*Marasmius* sp.).

St. Lucia :

Chlorotic streak, eye spot, gumming, pineapple disease, pokkah boeng, red rot, rind disease, root rot (*Marasmius* sp.).

St. Thomas :

Dry rot, eye spot, mosaic, pokkah boeng.

St. Vincent :

Gumming, root rot (*Marasmius* sp.).

Trinidad and Tobago :

Chlorotic streak (Trinidad), dry rot, eye spot, mosaic, pineapple disease, pokkah boeng, ratoon stunting, red leaf spot, red rot, red rot of leaf sheath (Trinidad), red spot of leaf sheath, red stripe (Trinidad), rind disease, ringspot, root rot (*Marasmius* sp.), sooty mold (Trinidad), stellate-crystal fungus.